Purchase Contract

(hereafter the "**Contract**")

1. CONTRACTUAL PARTIES

1.1 **Fyzikální ústav AV ČR, v. v. i.,**

with offices: Na Slovance 1999/2, 182 21 Praha 8,
represented by: Prof. Jan Řídký, DrSc. – Director,
Registered in the register of public research institutions of the Ministry of Education, Youth and Sports of the Czech Republic.

Bank: UniCredit Bank Czech Republic and Slovakia, a.s.
Account No.: 2106535627/2700
ID No.: 68378271
Tax ID No.: CZ68378271

(hereinafter the "**Buyer**")

and

1.2 **OptiXs, s.r.o.,**

with seat: Křivoklátská 37/3, 199 00 Praha 9,
represented by: Ing. Aleš Jandík, CEO,
registered at the Municipal court in Prague, No. C212818.

Bank: Československá obchodní banka, a.s.
Account No.: 269060882/0300
ID No.: 02016770
Tax ID No.: CZ02016770

(hereinafter the "**Seller**"),

(the Buyer and the Seller are hereinafter jointly referred to as the "**Parties**" and each of them individually as a "**Party**").

2. FUNDAMENTAL PROVISIONS

2.1 The Buyer is a public research institution whose primary activity is scientific research in the area of physics, especially elementary particles physics, condensed systems, plasma and optics.

2.2 The Buyer wishes to acquire the subject of performance hereof (**Universal cryogenic apparatus for measuring of physical properties in the magnetic fields**) in order to measure basic physical properties of solids, in particular fast and accurate characterization of magnetic, thermal and electrical properties over a wide range of conditions, namely temperature and magnetic field.

2.3 The Seller was selected as the winner of a public procurement procedure announced by the Buyer in accordance with Act No. 137/2006 Coll., on Public Procurement, as amended (hereinafter the "**Act**"), for the public contract called "**Universal cryogenic apparatus for measuring of physical properties in the magnetic fields**" (hereinafter the "**Procurement Procedure**").

2.4 The documentation necessary for the execution of the subject of performance hereof consist of

2.4.1 Technical specifications of the subject of performance hereof attached as **Annex No. 1** hereto.

2.4.2 The Seller´s bid submitted within the Procurement Procedure in its parts which describe the subject of performance in technical detail (hereinafter the "**Sellers's Bid**"); the Sellers´s Bid forms form **Annex No. 2** to this Contract and an integral part hereof.

In the event of a conflict between the Contract's Annexes the technical specification / requirement of the higher level / quality shall prevail.

2.5 The Seller declares that it has all the professional prerequisites required for the supply of the subject of performance under this Contract, is authorised to supply the subject of performance and there exist no obstacles on the part of the Seller that would prevent the Seller from supplying the subject of this Contract to the Buyer.

2.6 The Seller acknowledges that the Buyer considers the Seller's participation in the Procedure, provided that the Seller complies with all qualification requirements, as the confirmation of the fact that the Seller is capable, within the meaning of Sec 5(1) of the Act No. 89/2012 Coll., the Civil Code, as amended (hereinafter the "**Civil Code**") of providing performance under the Contract with such knowledge, diligence and care that is associated and expected of the Seller's profession, and that the Seller's potential performance lacking such professional care would give rise to corresponding liability on the Seller's part. The Seller is prohibited from misusing its qualities as the expert or its economic position in order to create or exploit dependency of the weaker Party or to establish an unjustified imbalance in the mutual rights and obligation of the Parties.

2.7 The Seller acknowledges that the Buyer is not in connection to the subject of this Contract, an entrepreneur, and also that the subject of this contract is not related to any business activities of the Buyer.

2.8 The Seller acknowledges that the production and delivery of the subject of performance within the specified time and of the specified quality, as shown in Annexes No. 1 and 2 of this Contract (including the handover and invoicing) is essential for the Buyer. If the Seller fails to meet contractual requirements, it may incur damage of the Buyer.

2.9 The Seller declares that he accepts the "risk of changed circumstances" within the meaning of Sec 1765(2) of the Civil Code.

2.10 The Contractual Parties declare that they shall maintain confidentiality with respect to all facts and information, which they learn in connection herewith and / or during performance hereunder, and whose disclosure could cause damage to either Party. Confidentiality provisions do not prejudice obligations on the part of the Buyer arising from valid legislation.

3. SUBJECT-MATTER OF THE CONTRACT

3.1 The subject of this Contract is the obligation on the part of the Seller to handover and transfer into the Buyer's ownership:

the **Universal cryogenic apparatus for measuring of physical properties in the magnetic fields** (hereafter the "**Equipment**")

and the Buyer undertakes to take delivery of the Equipment and to pay to the Seller the agreed upon price.

3.2 The following activities form an integral part of the performance to be provided by the Seller:

3.2.1 Transport of the Equipment incl. all accessories specified in Annexes 1 and 2 of the Contract to the site, un-packaging and control thereof,

3.2.2 Installation of the Equipment including connection to installation infrastructure at the site,

3.2.3 Verification of the Equipment's proper functionality and adjustment at the site,

3.2.4 Delivery of instructions and operating and repair manuals Equipment in Czech or English language to the Buyer, in electronic and hardcopy (printed) versions,

3.2.5 Training of operators at the site,

3.2.6 Free-of-charge warranty service including service inspections,

3.2.7 Provision of technical support in the form of consultations.

3.3 The subject of performance (Equipment) is specified in detail in Annexes No. 1 and No. 2 hereto.

3.4 The Seller shall be liable for the Equipment and related services to be in full compliance with this Contract, its Annexes, the submitted bid and all valid legal regulation, technical and quality standards and that the Buyer will be able to use the Equipment for the defined purpose. In case of any conflict between applicable standards it is understood that the more strict standard or its part shall always apply.

3.5 The delivered Equipment and all its parts, accessories must be brand new and unused.

4. PERFORMANCE PERIOD

4.1 The Seller undertakes to handover the Equipment properly after the initial installation, demonstrating its functionality and operator training within 8 months of the conclusion hereof, but no later than 30. 11. 2016.

4.2 The Seller shall notify the Buyer about the term of the delivery and installation of the Equipment min. 10 working days in advance.

4.3 The Buyer acknowledges that the Seller shall pay the price from public financial support with the

possibility of drawing bill by the end of 2016; for this reason, the Buyer is not interested in performance of a later date than laid down in Section 4.1 hereof.

4.4 The performance period shall be extended for a period during which the Seller could not perform due to obstacles on the part of the Buyer.

5. PREPAREDNESS OF THE PLACE OF HANDOVER

5.1 The Seller undertakes to perform a visit of the place of handover (installation) of the Equipment and verify that the site meets all the requirements necessary for installation (room dimensions, requirements for electrical outlet, room temperature, vibration, etc.) within 30 days of the conclusion hereof. The conditions required by the Seller shall not deviate from usual terms for installation of similar scientific equipment.

6. PURCHASE PRICE, INVOICING, PAYMENTS

6.1 The purchase price is based on the Seller's submitted bid and amount to 19.507.000,- CZK (in words: nineteen million five hundred and seven thousand CZK) excluding VAT (hereinafter the **"Price"**). VAT shall be paid by the Buyer and settled in accordance with the valid Czech regulation.

6.2 The Price represents the maximum binding offer by the Seller and includes any and all performance provided by the Seller in connection with meeting the Buyer's requirements for the proper and complete delivery of the Equipment hereunder, as well as all costs that the Seller may incur in connection with the delivery, installation and handover, and including all other costs of expenses that may arise in connection with creation of an intellectual property creation and its protection.

6.3 The Parties agreed that the Seller shall be entitled to invoice the Price as follows:

6.3.1 The advance payment corresponding to 30 % of the total Price in the amount of 5.852.100,- CZK excl. VAT after the conclusion hereof.

6.3.2 The Price will be invoiced after the handover protocol in accordance with Section 10.5 will have been signed between the Parties. The Handover protocol shall be attached to this invoice. This invoice shall be issued and delivered to the Buyer on the day of signing of the Handover protocol.

6.3.3 In case the Buyer accepted the Equipment with any minor defect or unfinished work, the Seller shall be entitled to invoice up to 85 % of the total Price in the amount of 16.580.950,- CZK excl. VAT after handover protocol in accordance with Section 10.5 will have been signed between the Parties. The remainder of the Price shall the Seller be entitled to invoice after removal / remedy of minor defects or unfinished work. The Handover protocol or the Buyer's confirmation of removal of minor defects or unfinished work shall be attached to these invoices.

6.4 Invoices issued by the Seller hereunder shall contain all the requirements stipulated by Act no. 235/2004 Coll., on Value Added Tax, as amended, and the Contract number.

6.5 The Buyer prefers electronic invoicing, with the invoices being delivered to efaktury@fzu.cz. All issued invoices shall comply with any international treaties prohibiting double taxation, if applicable.

6.6 Invoices shall be payable within thirty (30) days of the date of their delivery to the Buyer (hereinafter the **"Maturity Period"**). Payment of the invoiced amount means the date of its remittance to the Seller's account.

6.7 If an invoice is not issued in conformity with the payment terms stipulated by the Contract or if it does not comply with the requirements stipulated by law, the Buyer shall be entitled to return the invoice to the Seller as incomplete, or incorrectly issued, for correction or issue of a new invoice, as appropriate, within five (5) business days of the date of its delivery to the Buyer. In such a case, the Buyer shall not be in delay with the payment of the Price or part thereof and the Seller shall issue a corrected invoice with a new and identical Maturity Period commencing on the date of delivery of the corrected or newly issued invoice to the Buyer.

6.8 The Buyer shall be entitled to unilaterally set off against any receivables claimed by the Seller any of its payment due to:

6.8.1 damages caused by the Seller,

6.8.2 contractual penalties and other sanctions.

6.9 The Seller shall not be entitled to set off any of its receivables against any part of the Buyer's receivable hereunder.

7. OWNERSHIP TITLE

7.1 The ownership right to the Equipment shall pass to the Buyer by handover. Handover shall be understood as delivery and acceptance of the Equipment duly confirmed by Parties on the handover protocol.

8. PLACE OF DELIVERY AND HANDOVER OF THE EQUIPMENT

8.1 The place of delivery and handover of the Equipment shall be the premises of the Department 24 of the Fyzikální ústav AV ČR, v.v.i. at Cukrovarnická 112/10, Praha 6, Building A, room No. A33/1.

9. COOPERATION OF THE PARTIES

9.1 The Seller undertakes to notify the Buyer of any obstacles on its part, which may negatively influence proper and timely delivery and handover of the Equipment.

9.2 The Buyer undertakes to ensure such conditions that in the period between the delivery of the Equipment and begin of the installation no damage will incur to the Equipment.

9.3 The Seller shall notify the Buyer of improper preparedness of the place of handover (installation) within 14 days of execution of the visit pursuant to Section 5.1 hereof.

9.4 The Parties wish to deviate from provisions of Section 2126 of the Civil Code and agree that the Seller shall not be authorized to use institutes established therein.

10. DELIVERY, INSTALLATION, HANDOVER AND ACCEPTANCE

10.1 The Seller shall transport the Equipment at its own cost to the place of handover. If the shipment is intact, the Buyer shall issue delivery note for the Seller.

10.2 The Seller shall begin with the installation of the Equipment within 14 calendar days from the date of delivery.

10.3 The Seller shall perform and document the installation of the Equipment and launch experimental test in order to verify whether the Equipment is functional and meets the technical requirements of

Annexes No. 1 and 2 hereof.

10.4 Handover procedure includes handover of any and all technical documentation pertaining to the Equipment, user manuals and certificate of compliance of the Equipment and all its parts and accessories with approved standards.

10.5 The handover procedure shall be completed by handover of the Equipment confirmed by the handover protocol containing specifications of all performed tests (hereinafter the "**Handover protocol**"). The Handover protocol shall contain the following mandatory information:

10.5.1 Information about the Seller, the Buyer and any subcontractors,

10.5.2 Description of the Equipment including description of all components and serial numbers,

10.5.3 Description of performed tests including achieved parameters,

10.5.4 Confirmation of conducted training of operators,

10.5.5 List of technical documentation including the manuals,

10.5.6 Eventually reservation of the Buyer regarding minor defects and unfinished work including the manner and deadline for their removal,

10.5.7 Date of signature of the Equipment Handover protocol.

10.6 Handover of the Equipment does not release the Seller from liability for damage caused by product defects.

10.7 The Buyer shall not be obliged to accept the Equipment, which would show defects or unfinished work and which would otherwise not form a barrier, on their own or in connection with other defects, to using the Equipment. In this case, the Buyer shall issue a record containing the reason for its refusal to accept the Equipment.

10.8 Should the Buyer not exercise its right not to accept the Equipment with defects or unfinished work, the Seller and the Buyer shall list these defects or unfinished work in the Handover protocol, including the manner and deadline for their removal. Should the Parties not be able to agree in the Handover protocol on the deadline for removal of the defects, it shall be understood that any defects shall be removed / rectified within 48 hours from the handover and acceptance of the Equipment.

11. TECHNICAL ASSISTANCE - CONSULTATIONS

11.1 The Seller shall be obliged to provide to the Buyer free-of-charge consultations and technical assistance relating to the subject of performance hereof during the entire term of the warranty period. The Seller undertakes to provide to the Buyer consultations and technical assistance relating to the subject of performance hereof also after the warranty period expires.

12. REPRESENTATIVES, NOTICES:

12.1 The Seller authorized the following representatives to communicate with the Buyer in all matters relating to the Equipment delivery:

Ing. Aleš Jandík
e-mail: jandik@optixs.cz

tel. (+420) 607 014 292

12.2 The Buyer authorized the following representatives to communicate with the Seller:

RNDr. Jiří Kaštil, Ph.D.
kastil@fzu.cz
tel. (+420) 220 318 521

12.3 All notifications to be made between the Parties hereunder must be made out in writing and delivered to the other Party by hand (with confirmed receipt) or by registered post (to the Buyer's or Seller's address), or in some other form of registered post or electronic delivery incorporating electronic signature (qualified certificate) to epodatelna@fzu.cz in case of the Buyer and to info@optixs.cz in case of the Seller.

12.4 In all technical and expert matters (discussions on the Equipment testing and demonstration, notification of the need to provide warranty or post-warranty service etc.) electronic communication between technical representatives of the Parties will be acceptable using e-mail addresses defined in Sections 12.1 and 12.2.

13. TERMINATION

13.1 This Contract may be terminated early by agreement of the Parties or withdrawal from the Contract on the grounds stipulated by law or in the Contract.

13.2 The Buyer is entitled to withdraw from the Contract without any penalty from Seller in any of the following events:

13.2.1 The Seller fails to meet the deadline pursuant to Section 4.1 hereof.

13.2.2 Technical parameters or other conditions required in the technical specification defined in Annex No. 1 and 2 hereto and in the relevant valid technical standards will not be achieved by the Equipment at handover,

13.2.3 Facts emerge bearing evidence that the Seller will not be able to deliver and handover the Equipment.

13.2.4 The Seller will not meet the qualification criteria within the Procurement Procedure.

13.3 The Seller is entitled to withdraw from the Contract in the event of the Buyer being in default with the payment for more than 2 months with the exception of the cases when the Buyer refused invoice due to defect on the delivered Equipment or due to breach of the Contract by the Seller.

13.4 Withdrawal from the Contract becomes effective on the day the written notification to that effect is delivered to the other Party. The Party which had received performance from the other Party prior to such withdrawal shall duly return such performance.

14. INSURANCE

14.1 The Seller undertakes to insure the Equipment against all risks, in the amount of the Price of the Equipment for the entire period commencing when transport of the Equipment starts until duly handed over to the Buyer. In case of breach of this obligation, the Seller shall be liable to the Buyer for any damage that may arise.

15. WARRANTY TERMS

15.1 The Seller shall provide warranty for the quality of the Equipment for a period of 12 months. The warranty term shall commence on the day following the date of signing of the confirmation of removal of minor defects or unfinished work or on the day following the date of signing of the Handover Protocol pursuant to Section 10.5 hereof in case the Equipment was handed over without any minor defects or unfinished work. The warranty does not cover consumable things.

15.2 The Seller undertakes to provide free-of-charge service and regular service inspections in the extent defined by the manufacturer for the entire warranty term hereunder including repairs, supply of spare parts and transport and costs associated with employing a service technician.

15.3 Should the Buyer discover a defect, he shall notify the Seller to rectify such defect using the email address servis@optixs.cz. The Seller shall be obliged to respond to the notice of defect within 24 hours from notification and to send a technician for its remedy within 5 working days from notification.

15.4 The Seller shall be obliged to rectify any claimed defects on-site within 14 working days from receipt of the Buyer's notification. In cases of unusual defects, the Seller shall be obliged to rectify the defect in the period corresponding to the nature of the defect and to define the deadline for the handover of the rectified Equipment.

15.5 Any and all costs associated with defect rectification / repair including transport and travel expenses shall be always borne by the Seller.

15.6 The repaired Equipment shall be handed over by the Seller to the Buyer on the basis of a protocol confirming removal of the defect (hereinafter the "**Repair Protocol**") containing confirmations of both Parties that the Equipment was duly repaired and is defect-free.

15.7 The repaired portion of the Equipment shall be subject to a new warranty term in accordance with Section 15.1, which commences to run on the day following the date when the Repair Protocol was executed.

15.8 Should the Equipment suffer from defects which make it demonstrably unusable for a period exceeding 40 days (defect period) during any six (or less) consecutive months during the warranty term, the Seller shall be obliged to rectify such defect by delivering new defect-free Equipment in accordance with Section 2106(1)(a) of the Civil Code within 8 months from the date the Seller was called upon to deliver the new Equipment. The Equipment is demonstrably unusable, when the technical parameters or other conditions required in the technical specification defined in Annex No. 1 and 2 hereto and in the relevant valid technical standards are not met.

16. CONTRACTUAL PENALTIES

16.1 The Buyer shall be entitled to claim a contractual penalty against the Seller in the amount of 30 % of the Price, in case he will subsequently take advantage of the opportunity to withdraw from the Contract pursuant to Section 13.2.1 and 13.2.2.

16.2 The Buyer shall have the right to a penalty in the amount of 15.000,- CZK for each day when the Equipment was inoperational due to defect that was subject to warranty repairs, starting on the 15th day from notification of the defect. In cases of unusual defects, the penalty of 15.000,- CZK will be applied for each commenced day following the date of deadline for the handover of the rectified Equipment, specified in Section 15.4 hereof.

16.3 The Buyer shall have the right to a penalty in the amount of 10.000,- CZK for each commenced day of

delay with beginning the installation of the Equipment pursuant to Section 10.2 hereof.

16.4 In case the Seller delivers the duly issued invoice pursuant to Section 6.3.2 hereof after 5. 12. 2016, the Buyer shall have the right to a penalty in the amount of 100.000,- CZK.

16.5 In case of default in payment of any due receivables (monetary debt) under the Contract, the defaulting Buyer or Seller (the debtor) shall be obliged to pay a contractual penalty in the amount of 0.01 % of the owed amount for each commenced day of delay with the payment of the Price.

16.6 Contractual penalties are payable within 30 days of notification demanding payment thereof.

16.7 Payment of the contractual penalty does not prejudice the rights of the Parties to claim damages; The Parties exclude use of Sec 2050 of the Civil Code.

17. DISPUTES

17.1 Any and all disputes arising out of this Contract or the legal relationships connected with the Contract shall be resolved by the Parties by mutual negotiations. In the event that any dispute cannot be resolved by negotiations within sixty (60) days, the dispute shall be resolved by the competent court in the Czech Republic based on application of any of the Parties; the court having jurisdiction will be the court where the seat of the Buyer is located.

18. FINAL PROVISIONS

18.1 After delivery and handover of the Equipment hereunder the Seller shall provide to the Buyer a list of any subcontractors who received more than 10% of the Price for their performance hereunder pursuant to Section 147a of the Act.

18.2 This Contract represents the entire agreement between the Buyer and the Seller. The relationships between the Parties not regulated in this Contract shall be governed by the Civil Code.

18.3 In the event that any of the provisions of this Contract shall later be shown or determined to be invalid, ineffective or unenforceable, then such invalidity, ineffectiveness or unenforceability shall not cause invalidity, ineffectiveness or unenforceability of the Contract as a whole. In such event the Parties undertake without undue delay to subsequently clarify any such provision or replace after mutual agreement such invalid, ineffective or unenforceable provision of the Contract by a new provision, that in the extent permitted by the laws and regulations of the Czech Republic, relates as closely as possible to the intentions of the Parties to the Contract at the time of creation hereof.

18.4 This Contract becomes valid and effective as of the day of its conclusion by the authorised persons of both Parties.

18.5 This Contract may be changed or supplemented solely by means of numbered amendments in writing, furnished with the details of time and place and signed by duly authorised representatives of the Parties. The Parties expressly reject, within the bounds of Sec 564 of the Civil Code, modifications to the Contract in any other manner.

18.6 This Contract is drawn up in three (3) counterparts, each of which is deemed to be the original. The Seller shall receive two (2) counterparts, the Buyer shall receive one (1) counterpart.

18.7 The following Annexes form an integral part of the Contract:

Annex No. 1: Buyer's technical specification of the Equipment

Annex No. 2: Seller's technical specification

a) Technical specification on the subject of performance

b) Seller's bid in respect of part which technically describes the device

Annex No. 3: List of subcontractors who will receive more than 10% of the Price

18.8 The Parties, manifesting their consent with the entire contents of this Contract, attach their signature hereunder.

In Prague on 19. 02. 2016

For the Buyer: Fyzikální ústav AV ČR, v. v. i.

prof. Jan Řídký, DrSc.
Director

Fyzikální ústav AV ČR
veřejná výzkumná instituce
182 21 Praha 8, Na Slovance 2
- 1 -

In Prague on 17.2.2016

For the Seller: OptiXs, s.r.o.

Ing. Aleš Jandík
CEO

OptiXs s.r.o.
Křivoklátská 37, 199 00 Praha 9
IČ: 02016770 DIČ: CZ02016770
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Annex No. 1 – Buyer's technical specification of the Equipment

The purpose of the contract is the purchase of modular laboratory measuring apparatus enabling fast and accurate measurements of physical properties of solid substances in a wide range of temperatures (minimum and essential range of temperatures is from 350 K down to 2 K + extension to low temperature of 0.4 K for selected measurements) and magnetic fields (minimum range of magnetic fields is from 0 to 14 Teslas) The important is the temperature stability (better than 0.25% at maximum field) and magnetic field homogeneity at the sample position (supposed better than 0.25% / cm in all field ranges).

The apparatus must allow measurements, in particular, of **heat capacity**, **electrical resistance and electric DC voltage** on the sample powered by the electric current (possibly an AC method, too) in the temperature range from 0.4 K to 350 K and the external mg. field from 0 to 14 T. In addition this universal measuring device must enable accurate measurement of the magnetic response material in the form of: (i) **alternating magnetic susceptibility** in the acoustic frequency range (in the temperature range 2 K- 350 K with a frequency range of an alternating magnetic field tuneable at least by 3 orders of magnitude) and (ii) **DC magnetization** in the temperature range 2 K-350 K and an external field from 0 to 14 T. The heat transport properties of the samples - **thermal conductivity** and **thermoelectric coefficient** (also sometimes referred to as the Seebeck effect) - must be measurable in the temperature range of at least from 2 K up to 350 K and the magnetic field from 0 to 14 T.

The design of the instrument should be sufficiently flexible in the sense that it allows both easy and rapid replacement of the sample and the implementation of other experimental characterization in a given range of temperatures and magnetic fields that are not explicitly listed above. The requirement of realization of custom designed experimental characterization methods is linked with the requirement of connecting of own measuring instruments and their programming via bus communication devices; namely the software of the device must provide the ability to connect additional measuring instruments via GPIB interface (or equivalent). Modular measuring instrument should allow a maximum degree of automation.

Due to the nature of the instrument one assumes the use of liquid helium (He) for cooling and generating a magnetic field. It is therefore necessary, in the context of maximizing economy of operation, to optimize the thermal shield of the cryostat, whilst simultaneously ensuring the possibility of recovery of evaporated He, therefore, the possibility of connecting the measuring device to an existing system of He recuperation in the Institute of Physics. Evaporation of liquid He should be minimized via sufficient thermal insulation and the use of a liquid nitrogen shield. The measuring equipment should allow the installation and operation in a standard laboratory (meaning temperature and humidity) using existing power lines that meet applicable standards.

Detailed specifications given in Annex No. 2 a).

Annex No. 2 a) – Technical specification on the subject of performance

Tab. 1: Description and specifications of the offered Equipment:

The subject of performance in accordance with Sec 46(4) of the Act includes the following components and meets the technical requirements:

Description and minimum specification of the Goods as defined by the Buyer	Description and specification of the Equipment offered by the Seller	Complies YES/NO
Measuring of AC magnetic susceptibility Temperature range 2-350 K Sensitivity 10^{-7} emu, frequency range tuneable at least of 3 orders within the frequency range 10^{-1}-10^{4} Hz	**AC magnetic susceptibility option** **Part number: QD-P505A** Temperature range: 1.9 to 400 K Sensitivity: 1 x 10^{-8} emu at 10 kHz Frequency range: 10^{1} – 10^{4} Hz (3 orders, tuneable)	YES
Measuring of DC magnetization Temperature range 2-350 K Sensitivity at least 10^{-6} emu, Applied magnetic field between 0-14 T	**VSM option** **Part number: QD-P525** Temperature range: 1.9 to 400 K Sensitivity: 1 x 10^{-6} emu or 0.5% Applied magnetic field: 0 to ±14 T	YES
Measuring of specific heat Temperature range at least 0.4 – 350 K Applied magnetic field between 0-14 T Sensitivity at least 20 nJ/K at temperatures below liquid He, Possibility of individual programming of heating power and individual evaluation of acquired raw data.	**Heat capacity option, Helium-3 option** **Part number: QD-P650C, QD-P825C, QD-P826A** Temperature range with Helium-3: <0.4 to 350 K Temperature range without Helium-3: 1.9 to 400 K Applied magnetic field: 0 to ±14 T Sensitivity: 10 nJ/K at 2 K Individual evaluation of acquired raw data is possible. Individual programming of the heating pulse is possible ("long pulse feature" → Setting a temperature rise in percent or Kelvin).	YES
Measuring of electrical resistivity and electric voltage Temperature range at least 0.4 – 350 K, Applied magnetic field between 0-14 T Range of measurable resistivity: 1 mΩ–1 MΩ, Minimum sensitivity of electric voltage detection: ~50 nV	**ETO and DC option** **Part number: QD-P605B, QD-P400A** Temperature range with Helium3: <0.4 to 350 K Temperature range without Helium3: 1.9 to 400 K Applied magnetic field: 0 to ±14 T Resistivity range (DC option): 10 mW to 1 MW Resistivity range (ETO 4-wire): ~1 mW to 10 MW Resistivity range (ETO 2-wire): ~1 MW to 5 GW Sensitivity of voltage detection: 20 nV	YES

Measuring of thermal conductivity λ Temperature range at least 2 – 350 K, Applied magnetic field between 0-14 T Absolute range of measurement at ambient temperature within roughly 10^0-10^1 $Wm^{-1}K^{-1}$ for "standard" sample size corresponding to 10x2 x 2 mm, Dynamic range at least 20 in all temperature range, Measurement error better than 10% considering the dynamic factor, temperature detection sensitivity and radiation, i.e. reflecting the difficulties associated with measurement of extremely insulating and conducting materials (for λ at ambient temperature $\lesssim 0.25$ $Wm^{-1}K^{-1}$ or $\lambda \gtrsim 250$ $Wm^{-1}K^{-1}$), respectively.	**TTO option** **Part number: QD-P670B** Temperature range: 1.9 to 390 K Applied magnetic field: 0 to ±14 T Estimated range of measurement at ambient temperature: 10^{-1} – 2.5 x 10^0 W m^{-1} K^{-1} for samples L x (A) 2.5 x (5 x 5) mm^3 2 x 10^0 – 5 x 10^1 W m^{-1} K^{-1} for samples L x (A) 8 x (2 x 2) mm^3 10^1 – 2.5 x 10^2 W m^{-1} K^{-1} for samples L x (A) 10 x (1 x 1) mm^3 Dynamic range at least 20 in all temperature range, estimated dynamic range for all temperatures: ~25 or better (up to 1000). Measurement error better than 10%	YES
Measuring of thermoelectric power S Temperature range at least 2 – 350 K, Applied magnetic field between 0-14 T Sensitivity of thermoelectric voltage detection significantly better than 5 μV, Range of the measured thermoelectric voltages from ~ 10^0 μV up to ~ 10^3 μV Measurement error better than 10 % in all temperature range for absolute value S within the range 10^1-10^3 μVK^{-1} (For small absolute values of $\lvert S \rvert < 10 \mu VK^{-1}$ is the error of thermoelectric power measurement associated with sensitivity of the thermo-voltage detection and the criterion of maximum error below 10% is not valid)	**TTO option** **Part number: QD-P670B** Temperature range: 1.9 to 390 K Applied magnetic field: 0 to ±14 T Sensitivity of voltage detection: ±2 mV Measurement range: ~10^0 mV to ~10^5 mV Measurement error better than 10% in all temperature range for absolute value S within the range 10^1- 10^3 mV K^{-1}.	YES

Tab. 2

Table of the evaluation sub-criterion „Technical merit of the performance offered"	
Description	Value
Homogeneity of the magnetic field within 5 cm around the sample centre	±0.1% (over 5.5 cm x 1 cm diameter cylindrical volume)
Residual field strength of the magnet at the position of the sample	110 G (typical)

Annex No. 2 b) – The Seller's bid in the extent it describes technical parameters of the Equipment

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Nabídka vydaná

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Dodavatel

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Na Slovance 1999/2
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Česká republika

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Cukrovarnická 10/112
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Forma úhrady:
Způsob dopravy:

Termín
Vystaveno: 10.02.2016

Číslo poptávky

Označení dodávky	Množství	M.J.	Sleva [%]	Cena za M.J.	Sazba DPH	Základ [Kč]	Celkem [Kč]
14T PPMS system in configuration	1,00			19 507 000,00	21,00	19 507 000,00	23 603 470,00
PPMS with 14 Tesla Longitudinal Magnet	1,00			0,00	21,00	0,00	0,00
QD-PPMS-14							
PPMS AC Susceptibility Measurement CAN-based	1,00			0,00	21,00	0,00	0,00
QD-P505A							
Vibrating Sample Magnetometer System (VSM) incl. CAN tower (Model 1000)	1,00			0,00	21,00	0,00	0,00
QD-P525							
HC, Heat Capacity CAN based measurement option incl. cryopump (P640)	1,00			0,00	21,00	0,00	0,00
QD-P650C							
CAN based Helium-3 Refrigerator System with horizontal sample stage	1,00			0,00	21,00	0,00	0,00
QD-P825C							
Helium-3/ Heat Capacity compatibility kit	1,00			0,00	21,00	0,00	0,00
QD-P826A							
Resistivity Option	1,00			0,00	21,00	0,00	0,00
QD-P400A							
Electrical Transport Option (ETO)	1,00			0,00	21,00	0,00	0,00
QD-P605B							
Sample Wiring Test Station	1,00			0,00	21,00	0,00	0,00
QD-P150							
CAN TTO option, Thermal Transport System	1,00			0,00	21,00	0,00	0,00
QD-P670B							
Installation, training and warranty support	1,00			0,00	21,00	0,00	0,00
QDS-INSTALLATION							

Termín dodání do 8 měsíců od podpisu kupní smlouvy
Platnost nabídky 120 dní od konce lhůty pro podání nabídek

Vytiskl: Kateřina Binková
Stránka 1

Vytištěno systémem ABRA FlexiBee

Nabídka vydaná

NAV0036/1617

Rekapitulace DPH v Kč

Základ 0%	0,00	DPH 0%	0,00
Základ 10%	0,00	DPH 10%	0,00
Základ 15%	0,00	DPH 15%	0,00
Základ 21%	19 507 000,00	DPH 21%	4 096 470,00
Celkem	19 507 000,00		4 096 470,00

Základ [Kč]	**19 507 000,00**
Celkem [Kč]	**23 603 470,00**

OptiXs s.r.o.
Křivoklátská 37, 199 00 Praha 9
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Razítko a podpis

Registrace:
Registrováno u Městský soud v Praze pod číslem C 212818

Vytištěno systémem ABRA FlexiBee

Vytiskl Kateřina Binková
Stránka 2

Annex No. 2 b) – The Seller's bid in the extent it describes technical parameters of the Equipment

PPMS (Physical Property Mesuring System) in configuration:

1) **QD-PPMS-14** - PPMS with 14 Tesla Longitudinal Magnet
   - Probe with Sample Chamber and Puck Contact
   - Electronic Cabinet with
     - PPMS Controller
     - High Current Power Supply
     - Vacuum Pump
   - Computer, Monitor
   - MultiVu Software
   - Special High Capacity N2-jacketed Dewar
   - HTS Magnet leads

2) **QD-P505A** - PPMS AC Susceptibility Measurement CAN-based.

3) **QD-P525** - Vibrating Sample Magnetometer System (VSM) incl. CAN tower (Model 1000)

4) **QD-P650C** - HC, Heat Capacity CAN based measurement option
   Includes: cryopump (QD-P640), pucks

5) **QD-P825C** - CAN based Helium-3 Refrigerator System with horizontal sample stage

6) **QD-P826A** - Helium-3/ Heat Capacity compatibility kit (is required for use of heat capacity with helium-3 option)

7) **QD-P400A** - Resistivity Option
   Includes 1 universal puck and 2 DC resistivity pucks

8) **QD-P605B** - Electrical Transport Option (ETO) for PPMS

9) **QD-P150** - Sample Wiring Test Station

10) **QD-P670B** - CAN TTO option, Thermal Transport System

11) **QDS-Installation** - Installation, training and warranty support

Detailed description is in attached datasheetes

PPMS® Physical Property Measurement System

Our most versatile low temperature instrument

System features

PPMS cryogen-free EverCool II dewar and electronic console

The Quantum Design Physical Property Measurement System (PPMS) represents a unique concept in scientific laboratory equipment. It is an open-architecture, variable-temperature field system optimized to perform a variety of automated measurements.

Use the PPMS with our specially designed measurement options. It offers the widest range of magnetic, thermal and electrical measurement capabilities. At the same time, users may easily adapt the system to their own experiments and use it as automated platform to control the sample environment, which gives time to focus on the experiment. The sample environment allows fields of up to ±16 tesla and standard temperature ranges of 1.9 - 400 K.

Automation and ease of use

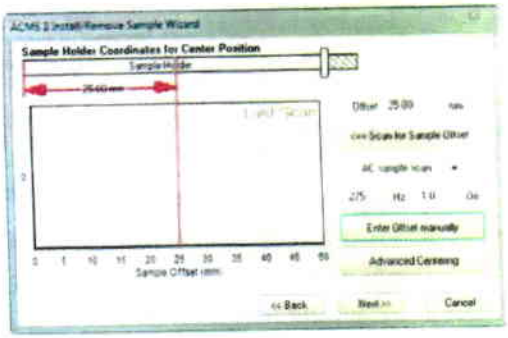
At Quantum Design we know your time is valuable, so we brought laboratory automation to a new level. While the PPMS automatically runs your measurements, you can analyze data from previous measurements, plan your next experiment, or synthesize and prepare new materials and samples.

Thanks to the modular design, each PPMS is specially configured to suit the particular research needs of different measurements. In the laboratory it is usually only a matter of minutes to change from one measurement application to another. To start the measurement you just need to insert the sample in the PPMS and create or open a sequence. The system will automatically perform the measurement and start to collect significant data. With remote access to the software from your office computer you can observe the system and measurement status. Furthermore, the PPMS is designed to run 24 hours a day on 7 days a week.

MultiVu software

PPMS MultiVu is a powerful software for the performance of complex measurements with a maximum of automatization. It allows both the measurement and evaluation of comprehensive data sets. Complex measurement sequences can be created by simply using click-and-drop. Data can be viewed in a graphic, tabular, or raw data format. The raw data may either be processed directly by MultiVu or exported as an ASCII file to be processed by the user.

Third party instruments (e.g. external current sources) may easily be controlled via MultiVu. This allows the user to create customized setups without losing the automation of the measurements runs.



Software example (ACMS II option)

Open architecture

The tremendous flexibility of the PPMS lets you create your own experiments and easily interface your own third-party instruments to the PPMS hardware. The PPMS MultiVu software supports linking capabilities, so you can write your own programs in Delphi, C++, or Visual Basic to synchronize PPMS functions with the activity of other instruments to perform your custom experiment. The model 6000 PPMS controller houses and controls all the important components of the instrument to provide direct communication with the application electronics for rapid data acquisition.

Much of the versatility of the PPMS is based on the design of the PPMS probe. The probe incorporates the magnet, the temperature control, and the sample puck connector.

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For your local contact click at: www.lot-qd.com

PPMS® Physical Property Measurement System

Our most versatile low temperature instrument

Sample mounting

The PPMS sample-mounting system is an interesting and unique feature of this instrument. At the bottom of the sample chamber is a 12-pin connector wired to the system electronics. This connector allows you to plug in a removable sample insert or sample "puck" and offers convenient access to electrical leads for application hardware and electronics. Most pucks include a thermometer in close proximity to your sample, some of the measurement pucks also include a heater. You can use this puck technology for integration of own experimental ideas.

Specialized pucks, 2.4 cm in diameter, are used for different measurement applications

PPMS sample chamber

Temperature control

To control the temperature, a helium gas is drawn into the annular region where heaters warm the gas to the correct temperature. This design reduces thermal gradients and increases system flexibility by making the sample chamber a controllable environment. For example, the sealed sample chamber may hold a high vacuum without the need for additional inserts. This is significant for options like heat capacity and the Helium-3 refrigerator.

The temperature control system offers the following features:

- Temperature sweep capability allows measurements to be taken while sweeping the temperature at a user-defined rate.
- Continuous Low-Temperature Control (CLTC) ensures precise temperature control, unlimited operation below 4.2 K, and smooth transitions through the 4.2 K helium boiling point.
- Temperature range of 1.9 – 400 K accommodates many different types of measurements.
- Optional capabilities can be used to extend the temperature range. A helium-3 or a dilution refrigerator are available to reach lower temperatures. The VSM option can run up to 1.000 K with an oven.

Configurable thermometry

The UserTemp feature makes it extremely easy for you to incorporate your own calibrated thermometer into the hardware so that your thermometer can control the system temperature. UserTemp not only reads the thermometer but also controls the helium gas flow and heaters to minimize the time required to stabilize at each selected temperature. Many of the PPMS options utilize this feature to monitor the temperature close to the sample.

Field control

The PPMS can be configured with a 9 T, 14 T or 16 T longitudinal magnet or a 7 T transverse magnet. The low noise, bi-polar power supply allows continuous charging through zero field with current compensation and over-voltage protection.

The self-contained ^{3}He Refrigerator lowers the minimum sample temperature to <0.4 K

PPMS® Physical Property Measurement System

Thermal measurements

Quantum Design offers two powerful thermal measurement options for the PPMS. The measurement of the heat capacity of solids can provide considerable information about the lattice, electronic, and even magnetic properties of materials. In measuring the thermal transport properties of a material the scientist can learn considerable information about the electronic as well as the ionic lattice structure of that specimen.

Heat capacity

To use the heat capacity option, mount the sample on an easy-to-install, plug-in microcalorimeter sample puck using the special sample-mounting fixture

The heat capacity measurement system performs fully automated relaxation heat capacity measurements. Each measurement is analyzed using a sophisticated two-tau model™ to accurately simulate the effect of the heat flow between the microcalorimeter platform and the sample (tau2) as well as the heat flow between the platform and puck stage (tau1). The heat capacity measurement system includes a high-vacuum system.

- Advanced heat capacity algorithms calculate the actual thermal coupling of the sample to the microcalorimeter platform, curve fit the data, and then compensate for this coupling when determining the heat capacity of the sample.
- A built-in data subtraction feature automatically removes the background heat capacity of the sample platform and adhesive.
- All calculated fitting parameters and raw data, including a χ^2 quality value, are saved in the data file.
- Application software automatically acquires, analyzes, and displays data.

Specifications	
Temperature range	1.9 – 400 K
Temperature extension	with low temperature stages (He-3, DR)
Sample size	1 – 500 mg
Resolution	10 nJ/K at 2 K
Pressure	High vacuum (<10^{-4} torr)
Optional	Puck with vertical sample alignment

Thermal transport option (TTO)

The thermal transport option (TTO) enables measurements of thermal properties, including thermal conductivity κ and Seebeck coefficient (thermopower) α. The system measures fully automated the thermal conductivity by monitoring a temperature drop as a known amount of heat passes through the sample. For the thermoelectric Seebeck effect the system measures the voltage drop across the sample as a heat pulse is applied. The temperature drop and the voltage drop are measured simultaneously and in combination with a four-probe resistivity measurement the so-called "thermoelectric figure of merit" ($ZT = S^2T/(\rho\kappa)$) is received, which is of main interest for the investigation of thermoelectric materials.

- Specially designed heater and thermometer shoes, which can be used for different sample shapes and which can be used in four-probe or two-probe configuration.
- Small and highly accurate thermometers feasible for the measurement of small temperature differences
- Ideal environment due to high vacuum in the sample chamber (TTO requires the high vacuum option)
- Sophisticated software which uses a dynamical model of the heat flow
- A continuous measurement while sweeping the temperature is possible as well as doing the measurement at a certain constant temperature

Specifications	
Measurement capabilities	Thermal conductivity κ Seebeck coefficient S Electrical resistivity ρ AC resistivity ρ Thermoelectric figure of merit ZT
Temperature range	1.9 – 390 K
Pressure	High vacuum (<10^{-4} torr)

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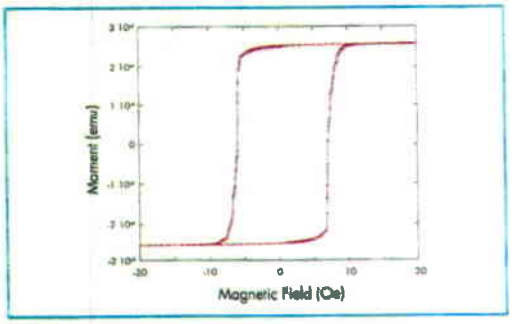
PPMS® Physical Property Measurement System

Magnetometry

Magnetometry applications are core options in the PPMS. The result is a powerful magnetic workstation for a broad range of magnetic sample characterizations.

Vibrating sample magnetometer VSM
The vibrating sample magnetometer (VSM) is a powerful measurement system to be used for magnetic sample characterization. The VSM option transforms your PPMS into a sensitive DC magnetometer for fast data acquisition. The movement of the sample is done by a special sample transport, which has a linear characteristic and thus is very precise and flexible. Further options extend the capability of the VSM.

- Rapid and completely automated centering operation of the sample.
- Sensitive DC magnetic moment measurement up to the maximum field of the magnet
- VSM measurement system is based on the CAN network protocol and includes the model 1000 CAN tower
- Sweeping of the magnetic field or of the temperature while doing the measurement is possible



Specifications	
RMS sensitivity	10^{-6} emu or 0.5%
Typical sample mass	<1 g
Oscillation amplitude (typical)	2 mm
Frequency	40 Hz
Coil-set bore	6.3 mm
Sample temperature	1.9 – 400 K
Typical data rate	1 s

Additional VSM possibilities
Several options are available to extend the PPMS-VSM set-up:

- VSM oven for temperatures above room temperature
- Large bore coil-set for measurements of larger samples (e. g. thin films)
- Ultra-low field setting using an active cancelation of the residual magnetic flux in the superconductive PPMS magnet
- Fiber optic sample holder (FOSH) for photo magnetic measurements
- Monochromatic light source based on a Xenon lamp for VSM-FOSH

VSM large bore specifications	
Coil-set bore	12 mm
RMS sensitivity (typical)	<1,5 x 10^{-4} emu/$\sqrt{Hz}$
VSM oven specifications	
Sample temperature range	300 – 1000 K
RMS sensitivity (typical)	<1 x 10^{-5} emu
Temperature precision	0,5 K
Temperature accuracy	2%
VSM ULF specifications	
Residual field	<0,1 Oe at any point
Residual field uniformity	<±0,1 Oe along 4 cm at the center of the coil-set
Included	Fluxgate sensor for field profiling

FMR spectrometer

Ferromagnetic resonance (FMR) is a spectroscopic technique to measure the magnetization of ferromagnetic material.

Specifications	
Temperature range	4 – 400 K
Frequency range	2 - 17 GHz

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PPMS® Physical Property Measurement System

Magnetometry

AC susceptibility option (ACMS-II)

ACMS-II coilset and CAN module

The AC measurement system (ACMS-II) provides you with the capability to perform both AC susceptibility and extraction DC magnetization measurements without changing the hardware. The ACMS-II is the newest version and has improved hardware and software.

- A single automated measurement sequence can perform both AC susceptibility and DC magnetization measurements
- High-speed digital filtering: By using a DSP the ACMS-II improves the signal-to-noise ratio over a wide frequency range
- A trim coil reduces environmental noise in AC susceptibility measurements

Specifications	ACMS-II
Temperature range	1.9 – 400 K
AC frequency range	10 Hz – 10 kHz
AC field amplitude range	5 mOe – 15 Oe
Sensivity range	
DC magnetization measurements	5×10^{-6} emu
AC susceptibility measurements	1×10^{-8} emu at 10 kHz
Temperature stability may be reduced at low temperatures due to sample movement.	

Torque magnetometry* (Tq-Mag)

Tq-Mag chip with integrated Wheatstone bridge

The PPMS model P550 torque magnetometer option (Tq-Mag) incorporates a torque-lever chip mounted on a PPMS horizontal or vertical rotator platform for performing fully automated, angular-dependent magnetic moment measurements at a wide range of fields and temperatures. Specifically designed for measuring small, anisotropic samples (e.g., single crystals, thin film samples, etc.), this highly sensitive torquemeter utilizes a piezoresistive technique to measure the torsion of the lever created by the applied magnetic field on the sample moment Tq-Mag provides excellent sensitivity in high magnetic fields normally not accessible in other measurement techniques. This torque detection system offers substantial immunity to gravity effects and minimal temperature dependence, which is accounted for in an automated calibration of the torque lever.

This option includes:

- Torque magnetometer chips
- Special rotator platform sample boards with chip holder
- Software module that integrates into the PPMS operating system

Tq-Mag may be used in both the longitudinal and transverse magnet configurations. The required rotator aids in locating the angle of the sample that gives the largest signal when measuring torque versus field.

Specifications	
Sample size	Up to 2 x 2 mm²
RMS Torque noise level	1×10^{-9} Nm for 40 sec. sampling time

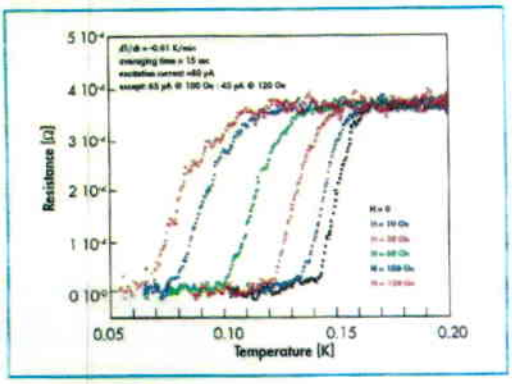
* Quantum Design developed the torque magnetometer in collaboration with the IBM Research Division, Zürich Research Laboratory, and the physical institute of the University of Zürich, Switzerland.

PPMS® Physical Property Measurement System

Electro transport

The PPMS offers automation and convenient sample mounting for all types of angular-dependent electro-transport measurements, including resistivity, hall effect, I-V curves, and your own experimental design. Let Quantum Design simplify your transport measurements.

Electro-transport option (ETO)



Electrical transport option on dilution refrigerator: resistance vs. temperature on sample of $Ir_{1-x}Ru_x$

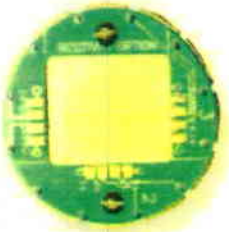
The electro-transport option (ETO) enables users to make several different types of electric transport measurements over a wide range of resistance values and sample types. It includes the measurement of AC differential resistance and I-V curves.

- Sample contact in two or four-probe configuration
- Two different channels for the simultaneous measurement of up to two samples
- Each channel consist of a high precision current source and a voltage preamplifier coupled to a digital signal processor.

Specifications	
Current range	100 nA to 100 mA in continuous operation
Frequency range	0.1 Hz to 200 Hz in AC (discrete steps)
Typical resistivity range	~1 μΩ to approx. 10 MΩ (4-wire mode)
	~1 MΩ to 5 GΩ (2-wire high resistance mode)

DC resistivity option

The DC resistivity option adds resistance bridge capability to the model 6000 PPMS controller. This bridge provides four independent channels that you can use for van der Pauw and four-wire resistance measurements (up to three samples in a single sequence).

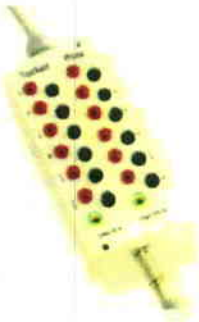


Puck for electric measurement

Specifications	
Current range	10 nA to 5 mA
Sensitivity	20 nV (typical)
Typical resistivity range	10 μΩ to 1 MΩ

Breakout box

The breakout box can be used for direct access to the sample chamber puck connector. It enhances the flexibility of transport measurements or can be just used for a direct access to sample signals.



Sample test box

With this box one can easily check sample mounting on a puck without placing the puck into the sample chamber.

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PPMS® Physical Property Measurement System

Electro transport

Horizontal rotator

Horizontal rotator with various sample-mounting platforms

You may take advantage of the horizontal rotator to obtain information about angular dependence. Samples are mounted on removable platforms. A thermometer, in direct contact with the platform, accurately determines the sample temperature. The rotator is available with standard or high-resolution motors.

Specifications	
The horizontal rotator option rotates the sample board about the horizontal axis.	
Range	-10° to 370°
Angular step size	0.053° for standard resolution; 0.0045° for high resolution
Compatible with	DC resistivity option Electro-transport option (ETO) Torque magnetometry option

Multi-function probe

The multi-function probe option extends measurement capabilities of the PPMS by allowing you to easily add hardware such as fiber optics, microwave guides, and external electrical leads to customize your experiment. This probe incorporates the PPMS sample space electrical connections and can utilize the electro-transport accessories.

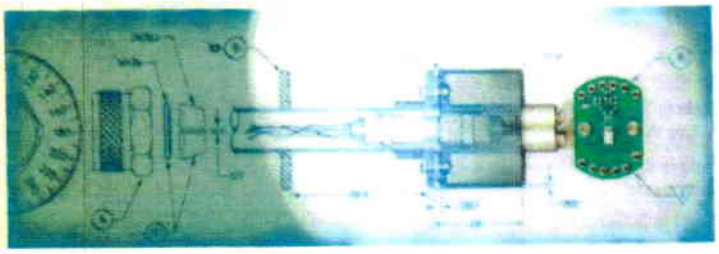
Pressure cell

For electric measurements under pressure a PPMS pressure cell is offered. The cell has a sample space of 4 mm diameter, 6 mm height and it fits into the puck connector. The HPC-33 pressure cell is compatible with the DC resisitivity option and the Electro-transport option (ETO).

For VSM measurements under pressure we offer the HMD-13 PPMS pressure cell. It requires the large bore upgrade for the VSM option and has a sample space of 2.2 mm diameter and 7 mm height. It provides a VSM adapter.

Pressure cell HPC-33 for electrical measurements

Specifications	HPC-33	HMD-13
Maximum pressure (load)	3.0 GPa	1.3 GPa
Maximum sample pressure @ 7 K	2.4 GPa	1.0 GPa
Sample space	4 mm x 6 mm	2.2 mm x 7 mm
Compatible with	ETO, DC	VSM



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PPMS® Physical Property Measurement System

Surface physics

Let your PPMS host an SPM insert and get new exiting possibilities. You just use the easy way of controlling the magnetic field and the temperature for surface investigation. The PPMS-SPM insert is manufactured by attocube systems and it offers atomic force, magnetic force, confocal microscopy or scanning hall probe microscopy measurements.

PPMS compatible scanning probe microscopy (PPMS-SPM)

- Suitable for a temperature range from 1.9 K to 300 K
- Suitable for magnetic fields up to 16 T
- Easily interchangeable SPM heads
- Large scan range (15 x 15 µm² at 4 K)
- Minimum drift in variable field/temperature.

Atomic/ magnetic force microscopy (AFM/MFM)

The PPMS-AFM is the perfect choice if it comes to demanding imaging applications such as high-resolution scanning of topographic or magnetic information of a sample under variable magnetic field or temperature.

- High spatial resolution imaging
- Alignement-free cantilever holder
- Fast sample and cantilever exchange

Specifications	
AFM type	Cantilever based, interferometric deflection detection
Imaging modes	Contact mode, non-contact mode
Measured RMS z-noise	0.05 nm (expected)
Contact mode @ 4 K, 5 ms pixel integration time	<0.15 nm (guaranteed for PPMS with liquid helium dewar or for reliquefier/ EverCool off)

Confocal microscopy (CFM) and Raman spectroscopy

Confocal microscopy is the method of choice for obtaining clear images with high spatial resolution (diffraction limit). The CFM setup is suitable for detection modes like reflection, luminescence, fluorescence and the optics can even be upgraded to make micro-Raman spectroscopy. High resolution confocal imaging

- Various detection modes such as reflection, luminescence, fluorescence, ...
- Interferometric deflection detection
- Large range, patented coarse positioning system

Microscopy setup	
CFM I	Free beam with an external optical head and low temperature objective. Optical setup with highest flexibility. Very broad range of application and high sensitivity
CFM II	Single mode fiber optic and low temperature objective. Designed for highest stability. Excellent long-term stability and highest sensitivity
Raman	Modular design with up to three optical channels Low temperature objective with ~550 nm confocal resolution. 2D Raman images

Applications

Nanostructure surface
- Surface plasmon waves
- Phase separation

Nanotube characterization and spectroscopy
- Graphene spectroscopy
- Quantum dots
- Diamond films and defects

Scanning Hall probe microscope (SHPM)

The SHPM is an ultra-compact scanning Hall probe microscope, designed for the operation at low temperatures and high magnetic fields. The heart of the SHPM is a GaAs/ AlGaAs sensor grown by molecular beam epitaxy. This Hall sensor can measure local magnetic fields with an unrevealed sensitivity and has the advantage in the ability to non-invasively obtain quantitative values. The Hall sensor is available as high resolution and ultra-high resolution version.

Specifications	
Sensor unit	MBE grown GaAs/AlGaAs Hall sensor
Imaging mode	Constant height
Active area	400 nm (high resolution), 250 nm (ultra-high resolution)

PPMS® Physical Property Measurement System

Low temperature stages

To reach temperatures below 1.9 K two optional refrigerator systems are available, a helium-3 and a dilution refrigerator. Both systems have a close-cycle gas design and operate fully automated.

Complete helium-3 system with probe, diaphragm pump, and cart

Helium-3 system

To reach temperatures below 1.9 K, an optional ^{3}He refrigerator is available. This probe provides a minimum temperature of less than 0.4 K. A new concept in refrigeration design, this self-contained Helium-3 refrigerator operates by continuously circulating ^{3}He in a closed-cycle, sealed system, eliminating the need for low-temperature seals and manual valves. The Helium-3 system provides fully automated control of the pumps to support measurement capability up to 350 K. This option is specifically designed to provide lower temperatures for heat capacity and electrotransport measurements. Cooldown time from 300 K to 0.5 K is less than three hours.

- No need for manually operation of any valve
- Easy plug-in of the probe in the sample chamber
- System is completely mounted on a moveable cart
- Horizontal or vertical oriented sample stage

Helium-3 probe

Specifications	
Temperature range	<0.4 K to 350 K
Cool-down time from 300 K to 0.5 K	3 h or less
Compatible with	DC resistivity Electro transport option (ETO) Heat capacity option

Dilution refrigerator

The dilution refrigerator system can be used for heat capacity and electro-transport option (ETO).

- Fully automated operation
- Easy plug-in of the probe in the sample chamber
- System is completely mounted on a moveable cart

Dilution refrigerator

Specifications	
Temperature range	50 mK to 4 K
Cool-down time from 300 K to 100 mK	8 h or less
Cooling power	2 mW at mixing chamber, 0,25 mW at sample chamber
Compatible with	Electro transport option (ETO) Heat capacity option User experiment

Adiabatic demagnetization refrigerator (ADR)

With the ADR insert, you can decrease the PPMS sample temperature range down to 100 mK.

The option is destined to be used for DC resistivity measurement for up to two simultaneously measured samples. This option is provided by our partner QD-Japan and has been designed in cooperation with Tohoku University.

Specifications	
Temperature range	300 K to 100 mK
Cooldown time (from 300 K)	3 h
Compatible with	DC resistivity

Quantum Design

LOT-QuantumDesign Europe

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PPMS® Physical Property Measurement System

Dewar and liquid helium saving options

The PPMS can be configured with different types of cryogenic dewars. From the classic liquid helium dewar with a vacuum shield to close-cycle systems with effective reliquefication technology, which makes the user independent from regular supply of liquid helium.

Standard dewar

The standard dewar has a hold time of up to 6 days.

Specifications	
Liquid helium capacity	30 L
Static boil-off with Probe	<5 L/d

High-capacity LN_2-jacketed dewar

This dewar upgrade reduce the consumption of liquid helium by approx. 40% and extends the time between a refill of liquid helium.

Specifications	
Liquid helium capacity	68 L
Static boil-off with probe	<3 L/d
Liquid nitrogen capacity	48 L
Static boil-off with probe	<2 L/d

Liquid helium dewar with ATL helium liquifier

The Advanced Technology helium liquefier (ATL) is an easy-to-use laboratory sized helium liquefier. It can liquefy helium gas from a gas cylinder or the evaporated helium gas from a cryostat. In combination with a PPMS system the helium gas could be directly recovered and transferred when needed. Please contact us for more questions or consult the ATL brochure.

Helium reliquefier

The reliquefier is the perfect add on for a high-capacity nitrogen-jacketed dewar. The vaporized helium is returned to a pulse-tube cooler, which is mounted over the PPMS dewar. After condensing the helium the liquid drips back into the PPMS dewar. As soon as your system is cold, there is no need for a refill of liquid helium. Any helium losses like flushing the sample chamber are compensated from a gas cylinder.

Specifications	
Liquefaction rate	10 L/day
Compressor type	water-cooled

EverCool-II dewar

The EverCool-II dewar makes your PPMS cryogen-free. You just start from helium gas at room temperature and a high-efficiency cold head is cooling down to 4 K and starts liquiefication. Even it is a cryogenfree system, the dewar still has some liquid helium, which offers the flexibility of turning-off the cold-head for a certain time.

Specifications	
Cool-down time	approx. 30 h
Liquefaction rate	approx. 8 L/day
Compressor type	air- or water-cooled

Comparison of reliquefier and EverCool II	
Reliquefier	**EverCool II**
Few vibrations (No effect on He^3 refrigerator, little effect on SPM)	Little space requirements
PPMS remains fully functional when the reliquefier is removed (e.g. for maintenance) and has its full helium capacity	Full automation
Upgrade can be done in the PPMS laboratory	Capable to cool down from helium gas only

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PPMS® Physical Property Measurement System

Base system specification

Magnet options	
Longitudinal	±9 T, ±14 T, ±16 T
Transverse	±7 T split coil
Field uniformity	
9 T longitudinal	±0.01% over 5.5 cm x 1 cm diameter cylindrical volume (typ.)
14 T longitudinal	±0.1% over 5.5 cm
16 T longitudinal	±0.1% over 1 cm DSV
7 T transverse	±0.1% over 1 cm DSV
Bi-polar power supply	
9 T longitudinal	50 A
Slew rate	1 – 19 mT/s (typ.)
14 T longitudinal	100 A
Slew rate	0.8 – 13 mT/s (typ.)
16 T longitudinal	120 A
Slew rate	1 – 22 mT/s (typ.)
7 T transverse	50 A
Slew rate	0.3 - 5 mT/s. (typ.)
Control modes	Persistent and driven modes
	Linear
	Oscillating
	No overshoot
Resolution	
9 T longitudinal	0.02 mT to 1 T
	0.2 mT to 9 T
14 T longitudinal	0.03 mT to 1.5 T
	0.3 mT to 14 T
16 T longitudinal	0.03 mT to 1.5 T
	0.3 mT to 16 T
7 T transverse	0.02 mT to 0.75 T
	0.2 mT to 7 T

UPS requirement	
Maximum current load	17 A

Temperature control	
Temperature range	1.9 – 400 K
Accuracy	±1% zero to full field (up to 16 T)
Slew rate	0.01 – 6 K/min.
Control modes	No overshoot fast settle temperature sweep
Stability	±0.2% for T <10 K (typ.)
	±0.02% for T >10 K (typ.)
Sample space	
Size	2.5 cm diameter
Electric contacts	12 accessable wires are available

PPMS utility inserts

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PPMS® Physical Property Measurement System

Integrated measurement applications

Chart of options

	Model	PPMS-0	PPMS-9	PPMS-14	PPMS-16	PPMS-7-Trans	PPMS-9 EverCool 2
Magnet		No magnet	Longitudinal	Longitudinal	Longitudinal	Transverse	Longitudinal
Field			9 T	14 T	16 T	7 T split-coil	9 T
Heat capacity	P650	✓	✓	✓	✓	✓	✓
TTO	P670	✓	✓	✓	✓	✓	✓
VSM	P525	✗	✓	✓	✓	✓	✓
VSM oven	P527	✗	✓	✓	✓	✓	✓
VSM large bore	P529	✗	✓	✓	✓	✓	✓
VSM-FOSH	P320	✗	✓	✓	✓	✓	✓
VSM-ULF	P701	✗	✓	✗	✗	✗	✓
ACMS II	P505	✗	✓	✓	✓	✗	✓
Torque	P550	✗	✓	✓	✓	✓	✓
DC resistivity	P400	✓	✓	✓	✓	✓	✓
Ferromagnetic resonance	FMR	✗	✓	✓	✓	✓	✓
ETO	P605	✓	✓	✓	✓	✓	✓
Horizontal rotator	P310	✗	✓	✓	✓	✗	✓
MFP	P450	✓	✓	✓	✓	✓	✓
Sample test box	P150	✓	✓	✓	✓	✓	✓
Breakout box	P-Box	✓	✓	✓	✓	✓	✓
Pressure cell	HPC	✓	✓	✓	✓	✓	✓
PPMS-SPM		✓	✓	✓	✓	✓	✗
Helium-3	P825	✓	✓	✓	✓	✓	✓
Dilution refrigerator	P850	✓	✓	✓	✓	✓	✗
ADR		✗	✓	✓	✓	(✓)	✓
Large dewar	P925	✓	✓	S	S	✗	✗
Reliquefier	P960	✓	✓	✓	✓	✗	✗
Helium liquefier	ATL	✓	✓	✓	✓	✓	✗

Description

✓	Available
✗	Not compatible or not a recommended combination
S	Included in the base system

PPMS Multi function probe (MFP)

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PPMS Vibrating Sample Magnetometer

Application Note

Long-Throw Linear Motor Sample Drive and Control Area Network (CAN) electronics tower

In its continuing effort to offer advanced measurement capabilities for the Physical Property Measurement System (PPMS), Quantum Design designed the P525 PPMS Vibrating Sample Magnetometer (VSM) application. The addition of the VSM to the current list of automated PPMS measurement applications makes this exceptionally versatile material characterization system even more powerful.

Model P525: PPMS Vibrating Sample Magnetometer

The Model P525 Vibrating Sample Magnetometer (VSM) measurement system for the Physical Property Measurement System (PPMS) is a fast, sensitive and fully automated DC magnetometer.

Benefits of the VSM System Design:

The VSM linear motor transport uses a uniquely designed linear motor to vibrate the sample. Unlike other vibrating sample magnetometers that use a short-throw resonant voice-coil design, you will find that the PPMS VSM linear motor is designed to operate at 40 Hz, with rapid slewing possible over about 6.5 cm of travel. The large range of motion enables the PPMS VSM system to perform rapid, completely automated centering operations - you will not need to perform manual adjustments to center the sample.

The sensitivity of the VSM detection coils is not significantly affected by large magnetic fields, so the PPMS VSM can perform sensitive measurements up to the maximum field available from your PPMS magnet. The VSM detection coil is inserted into the PPMS sample chamber by using the standard PPMS sample interface design. This procedure will make it easy to reconfigure the VSM option with alternate pickup coil designs in the future. You will find that you can change the pickup coil configuration as easily as you can change a sample puck.

You will find it easy to activate and de- activate the VSM option on your PPMS, just like the other PPMS options. The modularity of the design enables you to perform successive types of measurement with little additional effort. For example, you could follow state-of-the-art VSM measurements with heat capacity measurements by inserting a different sample puck or probe.

The PPMS VSM uses the next generation electronics architecture based on the CAN open networking protocol. The VSM option includes the Model 1000 modular control system, which is the heart of the new architecture. Plug-in modules, including the Model CM-A VSM motor module and the Model CM-B VSM detection module, provide option-specific functionality. This new modular architecture offers very high reliability as well as the ability to be expanded when you add options in the future.

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LOT Quantum Design

PPMS Vibrating Sample Magnetometer

Application Note

The Measurement:

The basic measurement is accomplished by oscillating the sample near a detection (pickup) coil and synchronously detecting the voltage induced. By using a compact gradiometer pickup coil configuration, a relatively large oscillation amplitude (1-3 mm peak) and a frequency of 40 Hz, the system is able to resolve magnetization changes of less than 10^{-6} emu at a data rate of 1 Hz. The VSM option for the PPMS consists primarily of a VSM linear motor transport (head) for vibrating the sample, a coilset puck for detection, electronics for driving the linear motor transport and detecting the response from the pickup coils, and a copy of the MultiVu software application for automation and control.

The sample is attached to the end of a sample rod that is driven sinusoidally. The center of oscillation is positioned at the vertical center of a gradiometer pickup coil. The precise position and amplitude of oscillation is controlled from the VSM motor module using an optical linear encoder signal readback from the VSM linear motor transport. The voltage induced in the pickup coil is amplified and lock-in detected in the VSM detection module. The VSM detection module uses the position encoder signal as a reference for the synchronous detection. This encoder signal is obtained from the VSM motor module, which interprets the raw encoder signals from the VSM linear motor transport. The VSM detection module detects the in-phase and quadrature-phase signals from the encoder and from the amplified voltage from the pickup coil. These signals are averaged and sent over the CAN bus to the VSM application running on the PC.

The system is designed to be user-installable and compatible with existing PPMS systems. Upgrading your current system will therefore be a simple process. Like the other PPMS applications, the VSM is used only when required, leaving the PPMS to run other applications as needed. Since the VSM system is a completely self-contained measurement application, other than one of the PPMS Base Systems, there are no other PPMS applications or options required for its use.

System Requirements:

The P525 VSM requires a PPMS computer system running Microsoft WindowsXP software. If upgrading an installed PPMS, it may be necessary to upgrade the computer to WindowsXP.

PPMS systems with serial numbers below P-087 may need to replace their Kepco magnet power supply with the new Quantum Design 50 Amp Bipolar Magnet Power Supply.

Systems with VSM require a minimum clearance height of 3m (10 ft) for sample exchange. Systems that have shielded dewars require a clearance height of 3.2m (10.5 ft).

System Specifications/Features

PPMS system properties:

- Temperature range: 1.9 K - 400 K.
- Magnetic field: up to16 tesla.
- Magnetic field ramp rate: determined by magnet and power supply.
- Temperature and magnetic field may be ramped during the measurement.

Geometry:

- Longitudinal configuration: magnetic field, VSM vibration and moment detection all along vertical axis.
- Coil-set bore: 6.3 mm
- Sample holders provided:
  Brass half tube: inner diameter = 3.3 mm; outer diameter = 3.6 mm
  Fused quartz paddle: diameter = 4 mm
- Coilset baseline: 9 mm
- Sample Mass <1 gram

VSM measurement parameters:

- VSM oscillation frequency (calibrated): 40 Hz
- VSM oscillation amplitude (typical): 2 mm peak - Range of 0.5 mm – 5mm
- Data rate and averaging window (typical): 1 sec - Range of 0.5 to 750 sec

Sensitivity using the above typical parameters and longitudinal coilset:

- rms sensitivity: $<10^{-6}$ emu or 0.5 %
- Relative Noise, Standard VSM:
  Larger of (6×10^{-7} emu + 3×10^{-7} emu/tesla)/√Hz or 0.5%/√Hz
- Relative Noise, EverCool VSM, with coldhead ON:
  Larger of (6×10^{-7} emu + 1×10^{-6} emu/tesla)/√Hz or 0.5%/√Hz
- Accuracy:
  0.5 %, using 2.8mm diameter x 4mm high cylinder (shape of Pd standard) or
  Better than 2% or 6×10^{-6}emu, whichever is greater
- Largest measurable moment: M_{max} [emu] = 40/(Peak Amplitude [mm])

(Note that when EverCool coldhead is OFF, the specification is the same as standard VSM)

Quantum Design

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PPMS Vibrating Sample Magnetometer

Application Note

Model P529
Large Bore Coilset

Geometry:

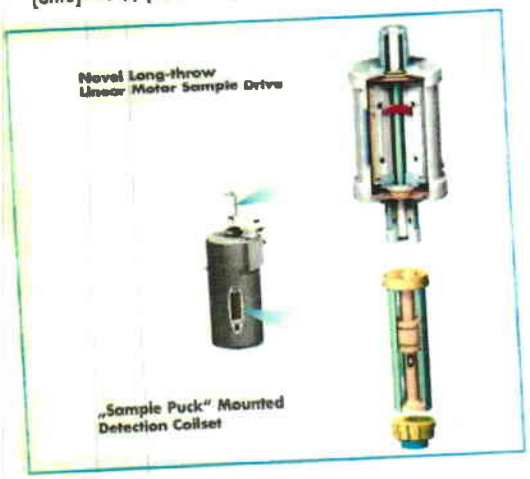
- Longitudinal configuration: magnetic field, VSM vibration and moment detection all along vertical axis.
- Coilset bore: 12.0 mm
- Sample holders provided:
  Brass half tube: inner diameter = 4.8 mm;
  outer diameter = 5.1 mm
  Fused quartz paddle: diameter = 4.0 mm
- Coilset baseline: 12.2 mm
- Sample Mass < 2 grams

VSM measurement parameters:

- VSM oscillation frequency (calibrated): 40 Hz
- VSM oscillation amplitude (typical):
  2 mm peak - Range of 0.5 mm – 5mm
- Data rate and averaging window (typical):
  1 sec - Range of 0.5 to 750 sec

Sensitivity using the above typical parameters:

- rms sensitivity: < 1.5×10^{-6} emu/√Hz
- Relative Noise, Standard VSM:
  Larger of (1.5×10^{-6} emu + 3×10^{-7} emu/tesla)/√Hz or 0.5%/√Hz
- Relative Noise, EverCool VSM, with coldhead ON:
  (TBD)
- Accuracy:
  0.5 %, using 2.8mm diameter x 4mm high cylinder (shape of Pd standard) or
  Better than 2% or 6×10^{-6}emu, whichever is greater
- Largest measurable moment: M_{max}
  [emu] = 75/(Peak Amplitude [mm])



Model P527
Vibrating Sample Magnetometer Oven

To increase the utility of the P525 PPMS Vibrating Sample Magnetometer (VSM), Quantum Design has developed an oven option that will give users the capability to make magnetic measurements from room temperature up to 1000 K.

This oven uses a heater and thermocouple integrated into the vibrating sample rod. A standard VSM detection coilset is used, while the PPMS sample chamber is maintained at 300 K in a high vacuum state (<10^{-4} torr required) during oven operation. A modular design allows the heater/thermometer sample holder to be easily removed from the sample rod for sample changing. The special sample rod has wire feedthroughs for the heater, thermocouple and a thermistor. The latter is used for correction of the thermocouple cold joint temperature. The heated region, including the sample, is wrapped in low emissivity copper foil to minimize heat leak from the hot region to the surrounding coilset.

Features/Benefits:

- Stable temperature control from 300 to 1000 K
- Durable construction of the sample rod (carbon fiber) and sample holder (zirconia)
- Convenient, easy and strong sample mounting
- Minimized radiation heat leaks

System Requirements:

- P525 Vibrating Sample Magnetometer (VSM) System
- P640 High Vacuum System required for thermal isolation

Specifications:

- Range of Temperature: 300 - 1000 K
- RMS Sensitivity: <10^{-5} emu or 0.5%
- Noise Floor: <10^{-5} emu rms (H = 0)
- Accuracy: <1×10^{-5} emu/ tesla
- Temperature Precision: 0.5 K
- Temperature Accuracy: 2%
- Specifications subject to change without notice.

Quantum Design

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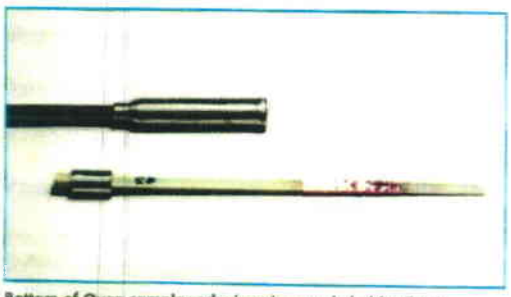
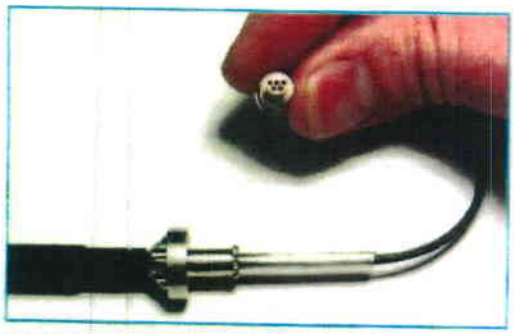
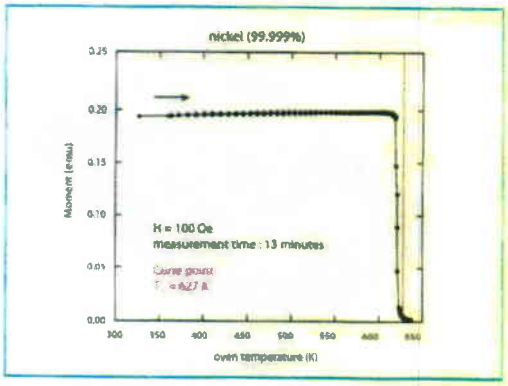
PPMS Vibrating Sample Magnetometer
Application Note



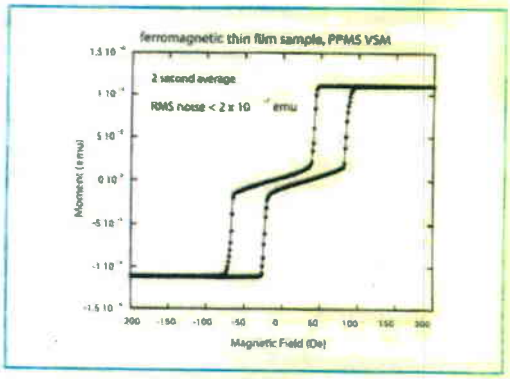
Bottom of Oven sample rod: zirconia sample holder (lower image), which plugs into the aluminum lower washer coupling.



Top of Oven sample rod: wires feed out of aluminum magnetic lock and end in a 5-pin connector, which plugs into a special sample transport cap at the top of the motor sample transport.



The temperature range of a prototype oven is demonstrated using a Ni standard. The Curie temperature of pure Ni is 627 K.



The sensitivity of the VSM is demonstrated on a thin film ferromagnetic sample provided by professor Y.U. Idzerda of Montana State University.

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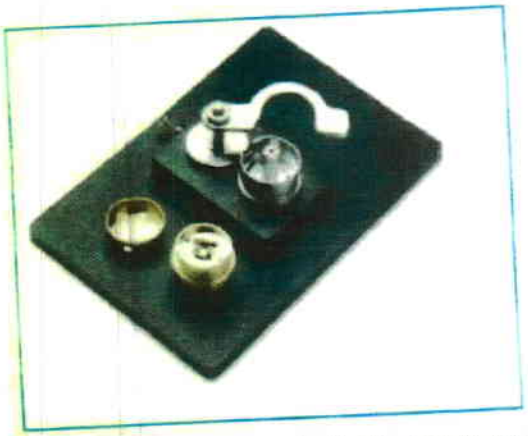
Advanced heat capacity with helium-3 for PPMS

Application note



The PPMS is the only system of its kind to offer automated measurement capability for the difficult field of heat capacity. By itself, the helium-3 refrigeration system provides a remarkable level of automation. Combined into one system, these two capabilities blend state-of-the-art instrumentation, hardware, and intelligent software with convenient sample mounting.

Unprecedented ease of use is the first feature of the PPMS heat capacity system (P650) that you will enjoy. Following a simple sample-mounting procedure, the sample mount is inserted into the PPMS sample chamber, measurement parameters are entered into the user-friendly software package and the measurement is initiated. The system automatically performs all the necessary temperature, field, and vacuum settings; the data acquisition and analysis; and the data plotting. The option uses a hybrid adiabatic relaxation method that combines the best measurement accuracy with robust error analysis.

The PPMS heat capacity option uses the basic PPMS to control environmental variables, such as the temperature and magnetic field, while specialized components perform the heat capacity measurement. The heat capacity option includes hardware and software that allow fully automated high-sensitivity heat capacity measurements to be routinely performed between 1.9 K and 400 K (< 0.4 K to 350 K with the helium-3 system) in magnetic fields up to 14 T.

The heat capacity system includes the following:

- Specialized heat capacity pucks (2) and sample frame (1)
- Precision electronics to control the measurement and gather the raw data
- P640 High-vacuum system to thermally isolate the sample
- A sample-loading station that allows convenient sample preparation
- Associated Windows™-based software that automatically performs sophisticated data analysis, addenda subtraction, thermometry calibration, and provides full automation via measurement sequences

Principle of operation

The heat capacity puck utilizes the standard PPMS 12-pin format for electrical connections, and it provides a small microcalorimeter platform for mounting the sample. Samples are mounted to this platform by a standard cryogenic grease or adhesive such as Apiezon N or H grease. The sample platform is suspended by eight thin wires that serve as the electrical leads for an embedded heater and thermometer. The wires also provide a well-defined thermal connection between the sample platform and the puck. An additional thermometer embedded in the puck provides a highly accurate determination of the puck temperature, and a thermal shield aids in maintaining stable sample temperature and uniformity. To ensure that heat is not lost via exchange gas, the heat capacity option includes the PPMS high-vacuum system (P640), which maintains the sample chamber pressure near 0.01 µbar and is automatically controlled by the software.

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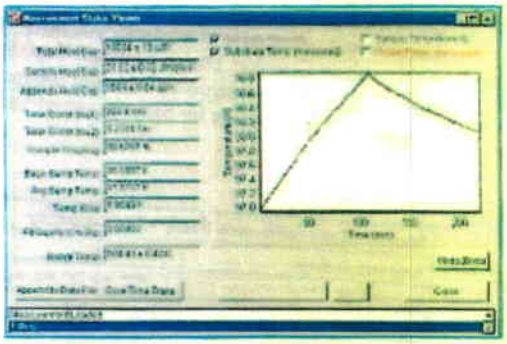
Advanced heat capacity with helium-3 for PPMS

Application note

Heat capacity dialog box prompts you to input required measurement parameters



Heat capacity measurement status viewer

The heat capacity mounting station helps protect the sample platform and its suspending leads when mounting and removing a sample. A built-in vacuum line securely holds the platform in place so that samples may be mounted or removed without generating stress on the supporting wires.

A single heat capacity measurement consists of several distinct stages. First, the sample platform and puck temperatures are stabilized at some initial temperature. Power is then applied to the sample platform heater for a predetermined length of time, causing the sample platform temperature to rise. When the power is terminated, the temperature of the sample platform relaxes toward the puck temperature. The sample platform temperature is monitored throughout both heating and cooling, providing (with the heater power data) the raw data of the heat capacity calculation.

Two separate algorithms fully automate the analysis of the raw data. The most general analysis method invokes the *two-tau model*™* which assumes that the sample is not in good thermal contact with the sample platform. The values of the heat capacity and other physical parameters are determined by optimizing the agreement between the measured data and the two-tau model. In the two-tau model, the first time-constant (tau 1) represents the relaxation time between the sample platform and the puck, and the second time constant (tau 2) represents the relaxation time between the sample platform and the sample itself. A second analysis is also performed using a simpler model that assumes perfect thermal coupling between the sample and the sample platform. The heat capacity software determines which model best fits the measured data and automatically saves the values of the sample heat capacity, addenda heat capacity, thermal coupling between the sample and the platform, thermal time-constants, and other information to the data file.

Additional features

- Advanced heat capacity algorithms calculate the actual thermal coupling of the sample to the microcalorimeter platform, curve fit the data, and then compensate for this coupling when determining the heat capacity of the sample.
- A built-in data subtraction feature automatically corrects for the background heat capacity of the sample platform and adhesive.
- All calculated fitting parameters and raw data, including a χ^2 quality value, are saved in the data file.
- The duration of a measurement is specified in terms of thermal time-constants rather than seconds. This implementation makes efficient use of the measurement time, because thermal time-constants may range from 100 ms at low temperatures to over 100 s at elevated temperatures.
- The PPMS verifies the electrical lead continuity and thermometry accuracy when the puck is installed. This verifies that the correct thermometer calibration file is used and that any unexpected electronic shorts or open circuits are detected before starting the measurement.
- Several heat capacity measurements may be automatically averaged.
- The units of a heat capacity measurement can be expressed as one of a variety of units, including specific heat.
- Debye temperature can be automatically calculated and written to the data file at every measurement point.

* A detailed explanation of the two-tau model is described as the "curve fitting" in "Measurement of Heat Capacity By Fitting the Whole Temperature Response of a Heat-Pulse Calorimeter" by Jih Shang Hwang, Kai Lin, and Cheng Tien, Rev. Sci. Instrum. Vol. 68 (1), January 1997, p. 94.

Advanced heat capacity with helium-3 for PPMS

Application note

The PPMS heat capacity option optimizes both the measurement accuracy and efficiency you have come to expect from Quantum Design products. Sophisticated analysis routines and integrated addenda subtraction automatically compensate for common experimental artifacts.

Specifications (with zero field) – heat capacity	
Temperature range	1.9 - 400 K
Sample size	1 - 500 mg (20 mg, typ.)
Resolution	10 nJ/K @ 2 K
Measurement accuracy	< 5%, 2 - 300 K < 2%, (typ.)

Helium-3 system (P825)

The helium-3 system, expands the temperature range of the PPMS below the standard 1.9 K temperature limit. This fully automated, closed-cycle ^{3}He probe installs easily into the sample space of the PPMS to extend the minimum experimental temperature to below 0.4 K. This option is compatible with the heat capacity, Resistivity, and AC Transport measurement capabilities. Incorporating all of its components into a cart, the helium-3 system can be rolled out of the way for safe storage when not in use. Only electrical cable connections are required to make the system active. This revolutionary system design has eliminated the need to manually operate any valves. The accompanying software provides fully automated control of the pumping system and temperature.

Design features

One of the benefits of the Quantum Design helium-3 system is that it is a continuously circulating system. Unlike traditional "one-shot" designs, this system implements a return line that allows ^{3}He to continuously flow back into the reservoir. Therefore, regeneration time is not required to maintain uninterrupted operation at low temperatures. However, for measurements that require temperatures below 0.5 K, the system can enter a one-shot mode by automatically activating a shut-off valve in the return line. Additionally, by utilizing the vacuum sealed sample chamber of the PPMS, no low temperature seals are required to use the ^{3}He probe. Consequently, leak testing is not necessary after mounting your sample, saving valuable hours each time a sample is introduced to the system.

helium-3 probe

Most importantly, the PPMS helium-3 system provides unprecedented ease of use. Working seamlessly with the PPMS, heat capacity and transport property systems, measurements may be performed without a need for the user to build additional hardware. The PPMS MultiVu software provides sequencing capabilities for automating all measurements. The software, without further input from the user, controls all pumps and system mechanisms. For example, to send the system to 0.5 K, you need to only insert the probe and enter the target temperature. Furthermore, with the helium-3 system installed, your measurements are not limited to lower temperatures. Without any user intervention, other then setting a sequence to higher temperatures, the system will perform measurements up to 350 K. You do no need to remove the probe or manually turn any valves to sweep temperature from 0.4 to 350 K.

Principle of operation

The base of the ^{3}He-refrigerator probe plugs into the 12-pin connector, which provides electrical access to the measurement hardware at the bottom of the PPMS sample chamber. Thermal anchoring baffles along the probe assist in cooling and maintaining the probe at a base temperature of 1.9 K. Two gas-handling lines run through the length of the probe: the pump line and the return line. ^{3}He gas flows down the return line and condenses into the reservoir in the base of the probe. A turbo pump mounted at the top of the insert pumps on the liquid ^{3}He via the pump line, thus reducing the temperature. This reservoir is thermally linked to the sample stage that houses a thermometer, heater, and the interface for the sample-mounting platforms. Samples are mounted on measurement-specific sample mounts that plug into the sample stage.

Complete helium-3 system with probe, diaphragm pump, and cart

Quantum Design

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LOT Quantum Design

Advanced heat capacity with helium-3 for PPMS

Application note

Temperature control is achieved by a combination of varying the speed of a specially designed turbo pump system and using a sample stage heater. Varying the speed of the turbo pump accommodates changes in the ^{3}He vapor pressure in the pumping lines and allows for different cooling powers. The sample stage heater rapidly ramps the temperature from the lowest temperature to 4 K, while the standard PPMS temperature control is invoked above 4 K.

After a sample is mounted to the sample stage and the refrigerator is subsequently inserted into the sample chamber, the PPMS cools the sample chamber to 1.9 K. Once the sample chamber is cold, the ^{3}He refrigerator is automatically activated and begins to condense ^{3}He. Since ^{3}He is constantly recycling, there is no limitation on how long the refrigerator will stay cold. This, however, does require the PPMS temperature control to hold the sample chamber at 1.9 K continuously, which requires the P800 Continuous Low-Temperature Control (CLTC) option.

Sample mounting

Sample mounting has been simplified by the use of plug-in sample mounts. Samples are mounted on these easy-to-handle platforms which plug into the stage that is connected to the cold finger of the refrigerator. Sample mounts may be swapped in a matter of minutes, minimizing the time required to change samples. The helium- 3 system ships with two heat capacity and three resistivity sample platforms.

PPMS system requirements

- P400 resistivity option
- P800 continuous low-temperature control (CLTC)
- P640 high-vacuum system (an integra component of the P650 heat capacity measurement system)

Specifications – helium-3	
Minimum temperature	Continuous mode < 0.5 K One-shot < 0.4 K
Measurement temperature range when helium-3 installed	< 0.4 K - 350 K
Cooling down time	300 to < 0.5 K in under 3 h (2 h typ.)

Quantum Design's expertise is blending a reliable and robust system design with components that allow a high degree of experimental access and functionality. Our trademark has always been to provide users with systems that maximize performance and automation.

Heat capacity and resistivity sample mounts for the helium-3 system

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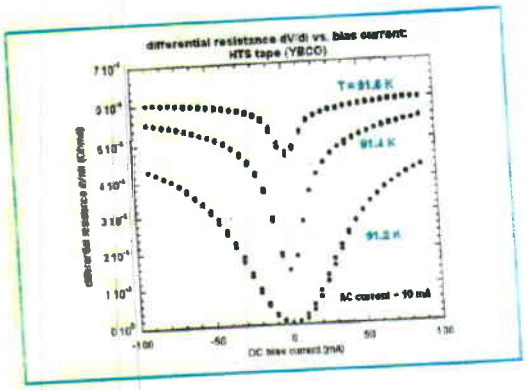
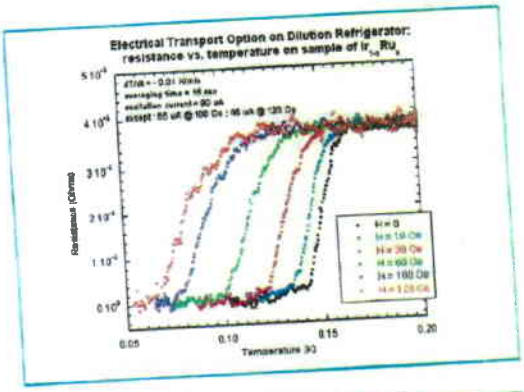
Electrical Transport Option (ETO) and DC Resistivity





Electrical Transport Option (ETO)

The P605 Electical Transport Option represents the next generation electrical characterization option for the PPMS family of instruments (PPMS, VersaLab, and DynaCool). The primary operating mode of this 2-channel measurement system uses an AC current excitation and digital lock-in voltage detection to perform 4-wire measurements of electrical resistance or Hall effect in samples of resistance up to several mega-Ohm. However, there are 3 major new capabilities which ETO adds to our electrical characterization suite:

- **High impedance mode:** the stimulus-response circuit can operate as an AC voltage source and a nanoammeter, thus allowing for 2-wire measurements of sample resistance up to 5 giga-Ohm.
- **AC+DC source:** the current source can superimpose a DC bias current I_{bias} on an AC signal, making it possible to use the lock-in to study differential resistance dV/dI versus I_{bias}. In high impedance mode, the excitation is an AC+DC voltage and the resulting current is detected so the measurement becomes dI/dV versus V_{bias}.
- **Two sources and meters:** there are two distinct sources and detection circuits which allows the 2 channels to operate truly independently. This is critical for applications such as measurements of resistance in the P850 Dilution Refrigerator where excitations should not be cycled on and off.

The measurement modes provided by ETO are as follows:

- resistance (2- or 4-wire): in 4-wire mode the Hall resistance can also be measured
- I-V curve tracing (2- or 4-wire)
- differential resistance dV/dI vs. I_{bias} (4-wire) and dI/dV vs. V_{bias} (2-wire)

Preamp specifications	
Noise	
HGA	1 nV/rt-Hz @ 100 Hz (typical) 2 nV/rt-Hz (maximum)
PGA	30 nV/rt-Hz (typical)
Voltage input range	±4.5 V at 1x gain
Current input range	±250 nA using the HZA*
Common mode rejection	-100 dB @ 100 Hz
Current source specifications	
Current range	10 nA to 100 mA continuous operation When using either the P850 Dilution Refrigerator System or the P825 Helium-3 System the current is limited to <20 mA to protect system wiring.
Frequency range	DC, and 0.1Hz to 200 Hz AC
Resistance specifications	
Absolute accuracy	0.1% (typical for R <200 kOhm) 0.2% (max. for R <200 kOhm)
Relative sensitivity	±10 nOhm RMS (typical)
Resistivity range	up to 10 MOhm in 4-wire mode (typical) 2 MOhm to 5 GOhm in 2-wire mode (typical)
System requirements	The P605 ETO is a CAN-based option. For proper operation it requires the use of either a VersaLab or, for the PPMS, the Model 1000 Modular Control System, which is included with the P525 VSM or ordered separately.
System incompatibilities	The P605 ETO is not designed to be used with the P670 Thermal Transport Option (TTO), which requires the P600 ACT.

* HZA = High Z Impedanz Amplifier

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Electrical Transport Option (ETO) and DC Resistivity

Accurate results combined with easy sample mounting, whether on removable Pucks or platforms, is the theme of the PPMS Electro-Transport System.

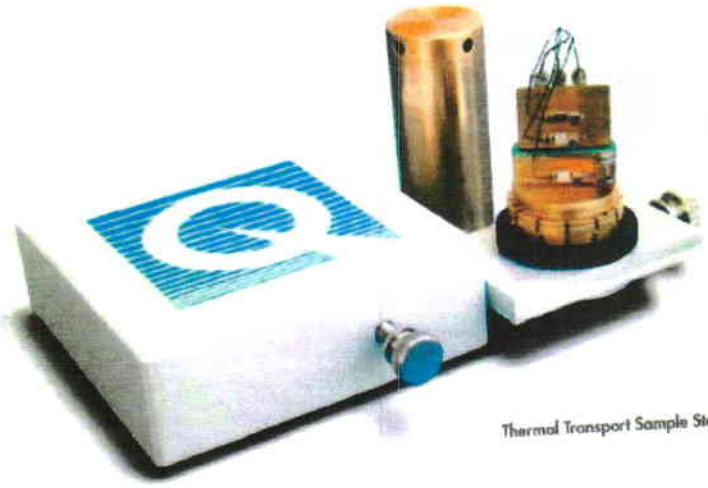
DC Resistivity

The model P400, DC Resistivity, provides four channels that you can use for 4-wire resistivity (up to three samples in a single sequence) and van der Pauw measurements.

Drive type	DC 7.5/8.3 Hz square wave
Current range	5 nA to 5 mA
Current step size	1% of range or 10 nA
Current stability	0.1% over 6 hours from 295 K to 297 K
Sensitivity	20 nV (typ.)
Compliance voltage	95 mV
Maximum resistance	4 MΩ
Precision	0.01% at 2 readings per s
Detection stability	0.1% over 6 hours from 295 K to 297 K

PPMS® Thermal Transport Option (TTO)

Model P670



Thermal Transport Sample Station

In measuring the thermal transport properties of a material specimen - such as thermal conductivity κ and Seebeck Coefficient α - a researcher can learn considerable information about the electronic as well as the ionic lattice structure of that specimen.

The P670 Thermal Transport System (TTO) measures thermal conductivity, or the ability of a material to conduct heat, by monitoring the temperature drop along the sample as a known amount of heat passes through the sample. The TTO measures the thermoelectric Seebeck effect as an electrical voltage drop that accompanies a temperature drop across certain materials. The TTO system can perform these two measurements simultaneously by monitoring both the temperature and voltage drop across a sample as a heat pulse is applied to one end. The system can also measure electrical resistivity ρ by using the standard four-probe resistivity provided by the Model P600 AC Transport Measurement System (ACT). All three measurement types are essential in order to assess the so-called "thermoelectric figure of merit," $ZT = \alpha^2 T/\kappa\rho$, which is the quantity of main interest if you are investigating thermoelectric materials.

While the measurements taken with the TTO system are quite elementary in principle, they have eluded commercialization because the data was typically very error prone, time consuming, and laborious, due, for example, to problems in controlling heat flow and accurately measuring small temperature differentials in a convenient manner. The TTO system has solved or greatly reduced many of these experimental complications. The TTO uses convenient sample mounting, small and highly accurate Cernox chip thermometers, and sophisticated software that dynamically models an AC heat flow through the sample and corrects for any heat losses that occur. The PPMS with the High-Vacuum option (Model P640) provides an ideal environment for the specially designed TTO sample puck, and the ACT option (Model P600) powers the sample heater and takes resistivity measurements.

The TTO system is set up to measure four thermal transport properties:

- Thermal conductivity
- Seebeck coefficient
- Electrical resistivity
- Thermoelectric figure of merit

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PPMS® Thermal Transport Option (TTO)

Model P670

Thermal conductivity κ is measured by applying heat from the heater shoe in order to create a user-specified temperature differential between the two thermometer shoes. The TTO system dynamically models the thermal response of the sample to the low frequency, square-wave heat pulse, thus expediting data acquisition. TTO can then calculate thermal conductivity directly from the applied heater power, resulting ΔT, and sample geometry.

Seebeck coefficient (also called the thermopower) α is determined by creating a specified temperature drop between the two thermometer shoes—just as it does to measure thermal conductivity. However, for Seebeck coefficient the voltage drop created between the thermometer shoes is also monitored. The additional voltage-sense leads on these thermometer shoes are connected to the ultra-low-noise preamplifier of the ACT system.

Electrical resistivity ρ is measured by using a precision DSP current source and phase-sensitive voltage detection. The specifications for this AC resistivity measurement are essentially identical to those for the P600 AC Transport Measurement System (ACT) option, because both TTO and ACT use the same high-performance hardware.

The dimensionless **thermoelectric figure of merit** ZT is determined here simply as the algebraic combination $ZT = \alpha^2 T/\kappa\rho$ of the three measured quantities—thermal conductivity, Seebeck coefficient, and electrical resistivity—discussed above.

Separate measurement protocols are provided for each of these measurements because these individual quantities maybe more accurately measured by using excitation currents and temperature differentials optimized for each situation. Limits for the parameters defining each measurement may be specified prior to running the measurement.

Each measured thermal transport property may be determined in either of the two measurement modes (continuous or single) supported by the TTO system. You select a measurement mode, and then you select the thermal properties to measure in that mode.

Benefits of the design of the TTO system include the following:

- Four-terminal geometry minimizes the effects of thermal and electrical resistance of the leads.
- Continuous measurements while slewing in temperature provide high density of data.
- Novel Adaptive Analysis technology simplifies measurements of unknown materials.
- Careful attention to the removal of effects of temperature drift, thermal radiation, and other systematic errors.
- Robust, easy-to-use, fully automated measurements.

System Requirements for the Thermal Transport System*

Component	Function
Resistivity Option (Model P400)	Provides the user bridge board that reads the two thermometer shoes.
AC Transport Measurement System (Model P600)	Outputs current to heater and sample while providing low-noise, phase-sensitive detection.
High-Vacuum Option (Model P640)	Provides thermal isolation for measurements. Cryopump or Turbo Pump version may be used.
MultiVu Software Version 1.1.6 or Later	Provides single user interface for PPMS and PPMS options.

* In addition to the requirements in table1-1, the PPMS Continuous Low-Temperature Control (CLTC) option (Model P800) is highly recommended. CLTC provides extended low-temperature control.

The Thermal Transport System is comprised of the following components:

- One TTO Sample Puck, which plugs into the PPMS sample chamber connector.
- One set of calibrated plug-in thermometer (2) and heater (1) shoes (probes).
- One set of uncalibrated plug-in thermometer (2) and heater (1) shoes (probes).
- An Isothermal Radiation Shield which screws onto the TTO Puck.
- A software module which installs into MultiVu.
- A nickel calibration sample for demonstrating and verifying proper operation
- A user's kit with tools and accessories for sample mounting

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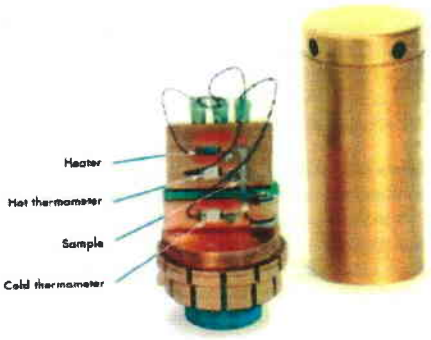
PPMS® Thermal Transport Option (TTO)

Model P670

Product Specifications/Features:	
Thermal conductance (k)	
Typical Accuracy	±5 % or ±2 μW/K, whichever is greater, for T <15 K
	± 5 % or ± 20 μW/K, whichever is greater, for 15 K < T < 200 K
	±5 % or ±0.5 mW/K, whichever is greater, for 200 K < T < 300 K
	±5 % or ±1 mW/K, whichever is greater, for T >300 K
Estimated dynamic range	1 - 25 mW/K for high T = 400 K
	100 μW/K - 100 mW/K for intermediate T = 50 K
	10 μW/K - 1 mW/K for low T = 1.9 K
Thermal conductivity κ = K(L/A)	
L = sample length [mm]	
A = sample X-section [mm²]	
Estimated dynamic range, T = 300 K, for given sample geometries: L x (A)	
2.5 x (5 x 5) mm³	κ : 0.1 - 2.5 W/m-K
8 x (2 x 2) mm³	κ : 2 - 50 W/m-K
10 x (1 x 1) mm³	κ : 10 - 250 W/m-K
Seebeck coefficient (S)	
Typical Accuracy	Error in S: ±5 % or, Error in S: ±0.5 μV/K or, Error in V: ±2 μV, whichever is greater
Approximate Range	1 μV/K - 1 V/K
Resistivity (P)	
AC Transport specifications for resistivity measurements apply in zero field.	
Maximum current	200 mA
Noise in field due to induction effects, 1 Hz measurement frequency	±1 mΩ, H = 9 T ±3 mΩ, H = 14 T

Thermoelectric figure of Merit ZT = S2T/(ρκ)	
Typical Accuracy	±15 % (When Seebeck coefficient and thermal conductivity 5% specifications apply)
Speed of acquisition	
Typically temperature slew rate	± 0.5 K/min, T > 20 K ± 0.2 K/min, T < 20 K 14 hour run from 390 to 1.9 K
System parameters	
Temperature	1.9 - 390 K
Magnetic Field	0 - 16 tesla*
Pressure	High Vacuum (<10-4 torr)

*Note: If you require use of significant magnetic fields (H > 0.1 T) at temperatures below T ~ 20 K, it may be necessary to correct for the magnetoresistance of the TTO thermometers using the QD Magnetoresistance Calibration Wizard.



Thermal Transport sample puck with radiation shield

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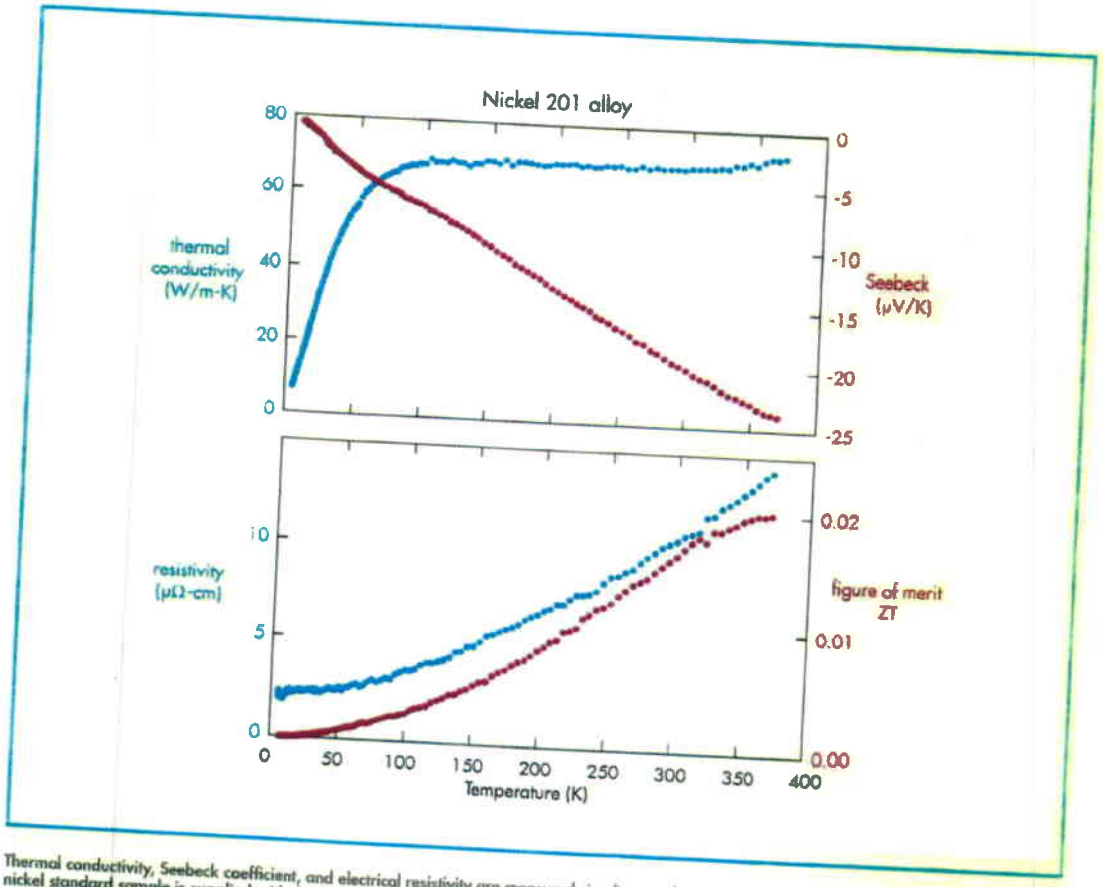
PPMS® Thermal Transport Option (TTO)
Model P670



Thermal conductivity, Seebeck coefficient, and electrical resistivity are measured simultaneously to determine the thermoelectric figure of merit. The nickel standard sample is supplied with the Thermal Transport Option.

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Annex No. 3 - list of subcontractors who will receive more than 10% of the Price

No.	Name, seat, ID/Tax ID, tel./fax, e-mail, Commercial Registry registration details, authorized person	Definition of that part which the Seller shall provide via the subcontractor	% share on the performance
1	LOT-QuantumDesign GmbH Im Tiefen See 58 64293 Darmstadt Germany Phone: +49 6151 8806-0 Fax: +49 6151 8806920 E-mail: info@lot-qd.de Registered office Darmstadt, Local Court Darmstadt, HRB 6538 DE284734472 Managing Director: Ralph Köhler & Dr. Jürgen Schlütter	Subcontractor is the manufacturer of the Equipment.	100