Purchase Contract

(hereafter the "**Contract**")

1. CONTRACTUAL PARTIES

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

with seat: Na Slovance 1999/2, 182 21 Praha 8,
represented by: RNDr. Michael Prouza, Ph.D., Director,
Registered in the Register of public research institutions of the Ministry of Education, Youth and Sports of the Czech Republic.

Bank: [redacted]
Account No. IBAN: [redacted]
ID No.: 68378271
Tax ID No.: CZ68378271

(hereinafter the "**Buyer**")

and

1.2 **Nicolet CZ s.r.o.,**

with seat: Praha 4, Klapálkova 2242/9, PSČ 14900,
represented by: RNDr. Ján Pásztor, Managing Director,
registered at the Municipal Court in Prague, Section C, Entry 80993.

Bank: [redacted]
Account No.: [redacted]
ID No.: 26422182
Tax ID No.: CZ26422182

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

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

EUROPEAN UNION
European Structural and Investment Funds
Operational Programme Research, Development and Education
MINISTRY OF EDUCATION, YOUTH AND SPORTS

2. FUNDAMENTAL PROVISIONS

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

2.2 The Buyer wishes to acquire the subject of performance hereof (the scattering near-field optical microscope for time-resolved spectroscopy in THz spectral range) in order to perform measurements of the conductivity and ultrafast photoconductivity in nanostructures.

2.3 The Buyer is the beneficiary of the subsidy for the project "**Solid state physics for the 21st century (SOLID 21)**", Registry No CZ.02.1.01/0.0/0.0/16_019/0000760 (hereinafter the "**Project"**), within the Operational Program Research, Development and Education (hereinafter the "**OP RDE**") of the provider Ministry of Education, Youth and Sports of the Czech Republic. The subject of public procurement will be co-financed by the EU Structural Funds.

2.4 The Seller was selected as the winner of a public procurement procedure announced by the Buyer in accordance with Act No. 134/2016 Coll., on Public Procurement, as amended (hereinafter the "**Act**"), for the public contract called **"Scattering near-field optical microscope for time-resolved spectroscopy in THz spectral range (Optický skenovací mikroskop v blízkém poli pro časově rozlišenou spektroskopii v terahertzové spektrální oblasti) – SOLID 21"** (hereinafter the "**Procurement Procedure**"). Both the Procurement Procedure and the Contract shall be governed by the Rules for applicants and beneficiaries of OP RDE, which are publicly accessible and are binding on the Parties.

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

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

2.5.2 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 **Annex No. 2** to this Contract and is 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.

2.6 The Seller declares that he 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 him from supplying the subject of this Contract to the Buyer.

2.7 The Seller acknowledges that the Buyer considers the Seller's participation in the Procurement Procedure, provided that the Seller complies with all qualification requirements, as the confirmation of the fact that the Seller is capable 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 his qualities as the expert or his 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.

2.8 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.

2.9 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 invoicing), is essential for the Buyer. If the Seller fails to meet contractual requirements, it may incur damage of the Buyer.

2.10 The 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 deliver and transfer into the Buyer's ownership:

the scattering near-field optical microscope for time-resolved spectroscopy in THz spectral range (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 Formulation of conditions which must be met at the place of Buyer in order to install the Equipment;

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

3.2.3 Installation of the Equipment including connection to installation infrastructure at the site;

3.2.4 Execution of the acceptance tests;

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

3.2.6 Training of operators at the site (at least two-day training of 2 operators);

3.2.7 Free-of-charge warranty service including service inspections;

3.2.8 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 stricter standard or its part shall always apply.

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

4. PERFORMANCE PERIOD

4.1 The Seller undertakes to manufacture, deliver, install and handover the Equipment to the Buyer within 5 months of the conclusion of this Contract.

4.2 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. PURCHASE PRICE, INVOICING, PAYMENTS

5.1 The purchase price is based on the Seller's submitted bid and amounts to 11 485 000 CZK (in words: eleven million four hundred and eighty-five thousand) excluding VAT (hereinafter the **"Price"**). VAT shall be paid by the Buyer and settled in accordance with the valid Czech regulation.

5.2 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 and its protection.

5.3 The Parties agreed that the Price shall be invoiced under the following terms:

5.3.1 The Seller is entitled to issue an advance invoice corresponding to 30 % of the total Purchase Price and amounts to 3 445 500 CZK excluding VAT after the conclusion of the Contract.

5.3.2 The remaining part of the Price shall be invoiced after the handover protocol in accordance with Section 10.4 will have been signed. In case the Equipment will be delivered with minor defects and / or unfinished work, the Price shall be invoiced after removal of these minor defects and / or unfinished work.

5.4 The invoice issued by the Seller as a tax document must contain all information required by the applicable laws of the Czech Republic. Invoices issued by the Seller in accordance with this Contract shall contain in particular following information:

5.4.1 name and registered office of the Buyer,

5.4.2 tax identification number of the Buyer,

5.4.3 name and registered office of the Seller, 5.4.4 tax identification number of the Seller,

5.4.5 registration number of the tax document,

5.4.6 scope of the performance (including the reference to this Contract),

5.4.7 the date of the issue of the tax document,

5.4.8 the date of the fulfilment of the Contract,

5.4.9 purchase Price,

5.4.10 registration number of the Project,

5.4.11 registration number of this Contract, which the Buyer shall communicate to the Seller based on Seller's request before the issuance of the invoice,

and must comply with the double taxation agreements, if applicable.

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

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

5.7 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.

5.8 The Buyer shall be entitled to unilaterally set off any of his payments against any receivables claimed by the Seller due to:

5.8.1 damages caused by the Seller,

5.8.2 contractual penalties.

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

6. <u>OWNERSHIP TITLE</u>

6.1 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.

7. PLACE OF DELIVERY OF THE EQUIPMENT

7.1 The place of delivery and handover of the Equipment shall be the room No. 63 in the main building of Fyzikální ústav AV ČR, v. v. i. (Institute of Physics AS CR), at Na Slovance 1999/2, 182 21 Praha 8, Czech Republic.

8. PREPAREDNESS OF THE PLACE OF DELIVERY

8.1 The Seller shall notify the Buyer in writing of the exact date of installation of the Equipment at least 28 days prior to such date, ensuring that the deadline for the performance hereunder is maintained.

8.2 The Buyer shall be obliged to allow the Seller, once the deadline set forth in Section 8.1 hereof expires, to install the Equipment at the place of performance.

9. COOPERATION OF THE PARTIES

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

9.2 The Buyer shall be entitled to receive information on the progress with the Equipment manufacture.

10. DELIVERY, INSTALLATION, HANDOVER AND ACCEPTANCE

10.1 The Seller shall transport the Equipment at his 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 perform and document the installation of the Equipment and launch experimental tests in order to verify whether the Equipment is functional and meets the technical requirements of Annexes No. 1 and 2 hereof.

10.3 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.

10.4 The handover procedure shall be completed by handover of the Equipment confirmed by the Handover Protocol containing specifications of all performed tests. The Handover Protocol shall contain the following mandatory information:

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

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

10.4.3 Description of executed acceptance tests (type of test, conditions, achieved parameters), in particular the verification of results of the functional performance and technical quality which were included in the bid evaluation, including verification of the achievement of the declared values, 10.4.4 List of technical documentation including the manuals,

10.4.5 Confirmation on training, its participants and extent,

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

10.4.7 Date of signature of the Equipment Handover Protocol.

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

10.6 The Buyer shall not be obliged to accept 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 his refusal to accept the Equipment.

10.7 Should the Buyer not exercise his 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 14 days from the handover of the Equipment.

11. TECHNICAL ASSISTANCE – CONSULTATIONS

11.1 The Seller shall be obliged to provide to the Buyer free-of-charge technical assistance by phone or e-mail relating to the subject-matter hereof during the entire term of the warranty period. The Seller undertakes to provide to the Buyer paid consultations and technical assistance relating to the subject-matter 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:

[redacted]

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

[redacted]

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 nicoletcz@nicoletcz.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, technical assistance 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 The Buyer is entitled to withdraw from the Contract without any penalty from the Seller in any of the following events:

13.1.1 The Seller is in delay with the handover longer than 4 weeks after the date pursuant to Section 4.1 hereof.

13.1.2 The technical parameters or other conditions required in the technical specification defined in Annex No. 1 and 2 and the declared values of the functional performance and technical quality which were included in the bid evaluation according to Section 10.4.3 will not be achieved during the handover of the Equipment.

13.1.3 Facts emerge bearing evidence that the Seller will not be able to deliver the Equipment.

13.1.4 The Seller will not meet the qualification criteria within the Procurement Procedure

13.2 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.

13.3 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.

14.2 The Seller is liable for the damage that he has caused. The Seller is also liable for damage caused by third parties undertaken to carry out performance or his part under this Contract.

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 Handover Protocol pursuant to Section 10.4 hereof. In case the Buyer accepted the Equipment with defects or unfinished work the warranty term shall commence on the day following the date of removal of the defects or unfinished work. The warranty does not cover consumable things.

15.2 Should the Buyer discover a defect, he shall notify the Seller to rectify such defect using the email address nicoletcz@nicoletcz.cz. The Seller is obliged to notify the Buyer without delay about any change of this email address. The Seller shall be obliged to review any warranty claim within 7 business days from receipt and to propose solution, unless agreed otherwise by the Parties.

15.3 During the warranty period the Seller shall be obliged to rectify any claimed defects within 14 business 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.

15.4 During the warranty period any and all costs associated with defect rectification / repair including transport and travel expenses shall be always borne by the Seller.

15.5 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.

15.6 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.

15.7 The Seller declares that he shall ensure post-warranty [out-of-warranty] service for the period of 10 years after the warranty term expires; the service terms shall be identical with provisions of Sections 15.2 and 15.3.

15.8 The Seller undertakes to provide the Buyer with updates of the software controlling the Equipment for the entire term of warranty service.

16. CONTRACTUAL PENALTIES

16.1 The Buyer shall be entitled to claim a contractual penalty against the Seller in the amount of 0,05 % of the Price for each commenced day of delay with the delivery pursuant to Section 4.1 hereof with a possible grace period of 10 days.

16.2 The Buyer shall have the right to a penalty in the amount of 0.05 % of the Price for each commenced day of delay with rectifying of claimed defects.

16.3 The Buyer shall be entitled to claim a contractual penalty against the Seller in the amount of 30 % of the Price, in case it will subsequently take advantage of the opportunity to withdraw from the Contract pursuant to Section 13.1.1 and 13.1.2.

16.4 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 0.05 % of the owed amount for each commenced day of delay with the payment.

16.5 All contractual penalties shall be payable within 30 days from the date claimed.

16.6 Payment of the contractual penalty does not prejudice the rights of the Parties to claim damages.

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. Disputes shall be resolved exclusively by the law of the Czech Republic.

18. FINAL PROVISIONS

18.1 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 Act No. 89/2012 Coll., the Civil Code, as amended.

18.2 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.

18.3 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 modifications to the Contract in any other manner.

18.4 The Parties expressly agree that the Contract as a whole, including all attachments and data on the Parties, subject-matter of the Contract, numerical designation of this Contract, the Price and the date of the Contract conclusion, will be published in accordance with Act No. 340/2015 Coll. on special conditions for the effectiveness of some contracts, publication of these contracts and Contract Register, as amended (hereinafter the "**CRA**"). The Parties hereby declare that all information contained in the Contract and its Annexes are not considered trade secrets under § 504 of the Civil Code and grant permission for their use and disclosure without setting any additional conditions.

18.5 The Parties agree that the Buyer shall ensure the publication of the Contract in the Contract Register in accordance with CRA.

18.6 This Contract becomes effective as of the day of its publication in the Contract Register.

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

Annex No. 1: Technical specification on the subject of performance

Annex No. 2: Technical description of the device as presented in Seller’s bid

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

In Prague	In Prague
For the Buyer:	For the Seller:
_________________________	_________________________
RNDr. Michael Prouza, Ph.D. Director	RNDr. Ján Pásztor Managing Director

Annex No. 1

Technical specification on the subject of performance as defined by the Buyer

	Specification and minimum requirements of the Equipment and of the warranty service as defined by the Buyer	Description and specification of the Equipment offered by the Seller	Complies YES/NO
	The system should involve the following parts:		YES
1.	Apertureless near field SNOM including atomic force microscope (AFM) device with an XYZ sample motorized coarse positioner and an XYZ fine scanner	NeaSNOM includes XVZ coarse positioner with positioning range X= 60 mm, V= 15 mm, z= 6 mm and fine scanner with range 100x100 µm X,V and 2.5 µm in Z axis	YES
2.	Optical high-resolution microscope integrated within the AFM device to image the sample in the visible light.	Optical high resolution Brightfield microscope with 5 Mpixel high-speed CCD-camera and approx . 0.75mm field of view	YES
3.	Parabolic mirror objective integrated into the SNOM microscope for tip illumination with THz radiation.	See the Tender technical support information	YES
4.	THz time-domain spectrometer with fiber-coupled emitter and detector (for easy alignment and improved stability) integrated within the AFM device set up to illuminate the scanning tip and collect the tip-scattered radiation.		YES
5.	Laser source unit(s) delivering femtosecond optical pulses to the THz spectrometer via optical fibers, and a time-synchronized free-space coupled output port for the optical pump pulses. These units must include appropriate femtosecond laser(s) and amplifier(s), a motorized stage controlling the delay between THz pulse and gating optical pulse used for the THz detection, and another independent motorized stage controlling the delay between the pump and THz pulses. The bundle must include optical fibers between laser/delay line units and THz emitter/detector		YES
6.	Auxiliary far field THz time-domain spectrometer for experiments outside the SNOM. It should allow an easy coupling into the Laser source unit and it must use separate elements from those integrated into the AFM device (fiber coupled THz emitter/ detector); the auxiliary experiment has to be compatible with primary vacuum environment.	Time-domain THz spectrometer. Compact design for 24/7 industrial and scientific applications. All-fiber coupled solution. Includes laser source, fiber coupled optical light path, fiber coupled delay line with >850ps scan range and control computer assembled in a compact 19" 3HU enclosure. THz wave path with THz emitter TERA15-TXFC and THz detector TERA15-RX-FC, and THz polymer optics included.	YES

7.	Control software for the SNOM operation enabling: control of all moving stages (XYZ stages, mirror objective and delay line units), control of the tip motion; real-time visualization of the optical image; acquisition, visualization and basic analysis of the THz image; export of results in the form of a text file or in a well-documented binary file	Part of delivery is NeaSPEC proprietary NeaSCAN control and acquisition software allowing all requested functions.	YES
	The system should fulfill the following minimum requirements:		YES
1.	Spatial resolution of the THz SNOM device: 100 nm or better (demonstration required during site acceptance tests)	Part of our offer is optical tip-sample interaction test with resolution better than 30nm and test of nanoscale spatial resolution at material with THz dielectric contrast with spatia l resolution bellow 50 nm	YES
2.	Spectral range of the THz SNOM device: at least 0.5 – 2 THz	See test 2.2.4 of supporting document with Spectral range O.S - 2.2. THz	YES
3.	Spectral range of the auxiliary THz setup: at least 0.15 – 3 THz The signal-to-noise ratio (SNR) of the auxiliary THz setup as delivered must be at least 2×10^3 in the range 0.15 – 1.5 THz under conditions specified below*. The dynamic range of the auxiliary THz setup as delivered must be at least 10^8 in the range 0.2-1 THz under conditions specified below*.	0.1- 3THz THz performance of auxiliary THz spectrometer: spectral range >S THz, dynamic range >90 dB.	YES
4.	The fine scanner must involve XYZ-axis closed-loop scanners with a resolution better than 0.5 nm (X,Y) and better than 0.2 nm (Z); range > 90 µm (X,Y) and > 5 µm (Z)	100 µm (X,V) / 2.5 µm (Z), resolution 0.2 nm (open-loop), 0.4 nm (closed-loop)	YES
5.	XYZ coarse positioner: resolution better than 200 nm, range > 50 mm (X), > 10 mm (Y), and > 5 mm (Z)	Coar se positioning ranges: X= 60 mm, V= 15 mm, Z= 6 mm X,V, Z resolution < 200nm	YES
6.	The THz SNOM must have easy sample loading without affecting the AFM tip position. It means that the AFM tip position must not be changed during sample exchange.	See the Tender technical support information	YES
7.	The parabolic mirror objective must have a numerical-aperture > 0.45 for improved SNR and for avoiding chromatic aberrations. Parabolic mirror adjustment must be fully motorized and enable one-click recall of alignment position for different operation modes and wavelengths	neaSNOM parabolic mirro r NA is 0.46	YES

8.	The parabolic mirror must support near-field THz-TDS measurements in forward-scattering geometry (i.e. one side emitter, the other side detector). Forward-scattering geometry has the advantage that the use of dispersive optical components (such as beam-splitters) can be avoided thus improving SNR of the THz near-field signal. To support a THz-TDS illumination/detection system, it must allow two independent optical beam paths a the same time (1) for AFM tip illumination and (2) for detection of scattered radiation.	See the Tender technical support information	YES
9.	The system must enable detection of near-field amplitude and phase simultaneously at every image pixel during a single image scan without the need to recover amplitude and phase in an image post-processing step.		YES
10.	The system must support multiple channels demodulation up to the 5th harmonic (to reliably distinguish the near-field and far-field signals) and at least 2 independent channels simultaneously for synchronization of AFM mechanics with optical signals		YES
11.	Integrated optical microscope must be equipped with sample inspection videocamera with < 0.6 µm spatial resolution and 0.75 mm (diagonal) field of view supported by at least 5 Megapixel CCD-camera with a speed of at least 25 fps.	See the Tender technical support information	YES
12.	The system must enable high optical access to AFM tip (180° horizontal, 60° vertical)	See the Tender technical support information	YES
13.	Pump pulse (delivered through free-space coupled output port) characteristics: central wavelength 800 nm +/- 50 nm, pulse length < 120 fs, linear polarization, average power > 100 mW; time synchronized with the THz pulses		YES
14.	The delay line length for the THz measurements must be at least 500 ps (to allow the spectral resolution in auxiliary experiments of 2 GHz)		YES
15.	THz beam alignment must be a routine procedure (without dismounting the device and optics); e.g. SNOM must involve integrated visible light alignment sources		YES
16.	Focusing of the THz beam onto the AFM tip and collecting of the THz scattered light must be based on reflective optics to avoid dispersion of the broadband radiation		YES

17.	The path of the optical pump beam between the free-space coupled output port and the SNOM will be built by the customer; the manufacturer must design a suitable optical path for the integration of the visible pump beam inside the SNOM; the manufacturer must also demonstrate that the time delay between THz and pump pulse at the SNOM sample position is in the range of at least –20 to 500 ps		YES
18.	The SNOM electronics must involve raw signal output (tip-modulated output) for possible external lock-in signal processing supplied by the customer and a DC input for the acquisition and software treatment of such signal		YES
19.	Control of the time delay for the near-field THz-TDS must be implemented in the complete system control software in order to enable THz spectroscopy at given locations, along defined lines or arrays within a previously scanned sample area		YES
20.	The control software must support 1D (approach curve), 2D (AFM/THz-SNOM image) and 3D (i.e. approach curve at every image pixel and THz time-domain spectroscopy at every image pixel) scans. The software should also have a friendly graphical user interface and provide automatic routines (e.g. for automatic tuning of the cantilever or automatic focusing and optimization of the optical signals) for easy learning and operation of the system		YES
21.	The length of the warranty for the complete delivered THz-SNOM system and auxiliary THz setup must be at least 12 months.		YES
22.	Assistance for fast diagnostics of the system should be provided within maximum 2 working days upon system failure reported by the customer		YES
23.	The technical support for all kinds of repairs should be available within EU		YES
24.	Guaranteed delay of the on-site intervention should be at most 25 days after a problem/failure reported by the customer		YES

*The signal-to-noise (SNR) and dynamic range (DR) calculations are strictly based on statistics of the measured quantities. Conditions and the measurement protocol are described below [theoretical background: V. Skoromets

et al, J. Infrared Milli. THz Waves, **39**, 1249 (2018)].
- The experimental setup delivered by the bidder will be used
- Experiment will consist of *N* multiple waveform measurements (accumulations), $N \geq 1000$
- Acquisition time for a single scan (single accumulation) is denoted *t*
- Scan length in time delay units (ps) is denoted t_{scan}
- Maximum useful frequency (bandwidth) is $f_{max} = 3$ THz
- Acquisition time spent per single useful point [see Skoromets et al.] is $\Delta T = Nt / (2 f_{max} t_{scan})$
- Test experiment: *N* time-domain accumulations without any sample in the beam path will be measured, Fourier transformation of individual accumulations will be calculated
- Statistical analysis will be performed on frequency domain accumulations: average value of the field amplitude *E* and its standard deviation σ will be calculated for each frequency
- The standard deviation will be normalized, i.e. multiplied by $\sqrt{\Delta T}$, as defined above. (This ensures an acquisition time of 1 s per useful spectral point independently of particular conditions)
- $SNR = E(\omega) / 2\sigma_E(\omega)$ is the normalized SNR, where $\sigma_E(\omega)$ is the normalized standard deviation defined above
- *N* time-domain accumulations will be measured with the beam path completely blocked by a metal piece (background measurement), Fourier transformation of individual accumulations will be calculated
- normalized standard deviation of the background $\sigma_B(\omega)$ will be calculated as described above
- $DR = E^2(\omega) / \sigma_B^2(\omega)$ is the normalized DR.

The evaluated parameters according to the evaluation criterion „Functional performance and technical quality" are listed in this table:

Parameter as defined by the Buyer	Value and specification of the Equipment offered by the Seller
spatial resolution of the SNOM in the THz range: z-direction confinement[1] (nm)	Bellow 30 nm
spatial resolution of the SNOM in the THz range: x-y resolution[2] (nm)	XY 50 nm, with special tips 13 nm (see C. Maissen et al., *ACS Phot.* 6, 1279 (2019)
Signal-to-noise ratio of THz spectrally integrated near-field signal[3]	**S/N** = 30
Scientific impact of the device: number of scientific papers in peer-reviewed journals with impact factor > 2 (according to WOS 2018 edition) obtained with the bidder's THz-SNOM.	15 scientific papers, details in attached list of reference publications for neaSNOM THz nanoscopy

[1] z-direction confinement of the near-field interaction determined by approach curve measurements: specify the distance between the tip and the sample at which the decay of the normalized near-field signal from 1 to 1/e occurs.
[2] x-y resolution test is determined by measuring (in THz spectral range) the line profile across two materials with different refractive indexes (metal-dielectric); specify the distance at which the contrast change 30-70% is observed.
[3] SNR of the THz signal is recorded on a high-resistivity Si surface 25x25 pixels with 5ms/pixel; the detection time-delay is set to a fixed point of the THz waveform; the signal is measured with an integration time of at most 5 ms; the noise level is calculated as the standard deviation of the average signal value over 25x25=625 pixels.

Annex No. 2

The Seller's bid in the extent it describes technical parameters of the Equipment

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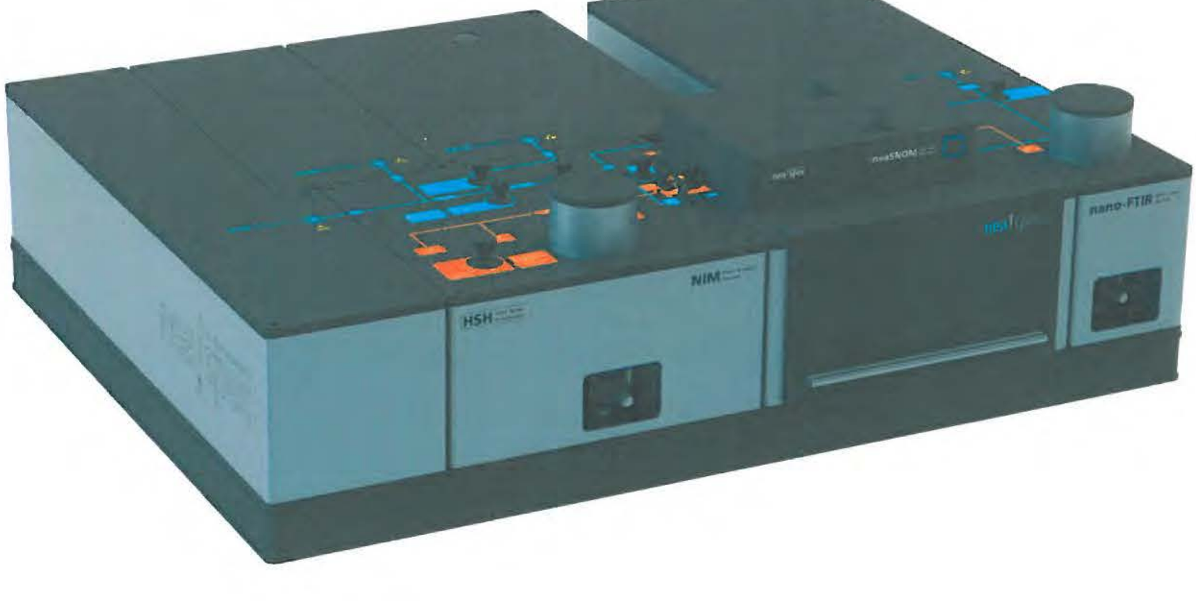
e-mail: nicoletcz@nicoletcz.cz www.nicoletcz.cz
Tel./Fax: 272 760 432, 272 768 569

Nabídka na Near-Field Scanning Optical Microscope

Nabídka číslo: **N381/19**



Červenec 2019, Praha

Nicolet CZ s.r.o., Klapálkova 2242/9, 149 00 Praha 4
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Tel./Fax: 272 760 432, 272 768 569

Popis nabízené sestavy (description):

	Popis	Part Number	Počet
1	**neaSNOM (Near-Field Scanning Optical Microscope)** - Apertureless near-field scanning technology (s-SNOM, no fibers required) - Accepts visible, infrared and even THz illumination wavelength while spatial resolution is only determined by AFM-tip size, typically 10 - 20nm - Suited to analyze organic and inorganic materials - Requires only standard AFM sample preparation	**NS-17**	**1**
	Atomic Force Microscope (AFM) - High-stability AFM optimized for nanoscale optical imaging & spectroscopy - Compact size X,Y,Z: 30 cm x 45 cm x 30 cm	**AFM-2**	**1**
	AFM Sample Positioner and Scanner	**SPS - 3**	
	Motorized Sample X,Y,Z Coarse Positioner - Easy sample loading and selection of region of interest - Coarse positioning ranges: X = 60 mm, Y = 15 mm, Z = 6 mm - X,Y,Z resolution < 200nm	**SCP - 1**	
	X-Y Sample Scanner - Scanning sample design to allow AFM tip illumination - 100 µm x 100 µm X,Y closed-loop scan range - X,Y resolution: 0.2 nm (open-loop), 0.4 nm (closed-loop) - Scan-speed: up to 20 µm/s - Scan-time for e.g. 100 x 100 pixel = 1 x 1 µm image : 60s - Maximum sample size: 40 x 50 x 15 mm (X,Y,Z)	**SS-100**	
	Z-Axis Sample Scanner - ≤ 0.2 nm noise-limited z-resolution (RMS) 1 - Max. 2.5 µm z-range (upgradeable to 8 µm)	**SSZ-25**	
	AFM Probing Head - Accepts standard AFM cantilevers up to 500 kHz resonance frequency - Ultra-high optical access to AFM tip (180° horizontal, 60° vertical) - Motorized positioning (X,Y,Z) for easy AFM-tip alignment - Head positioning ranges: X = 30 mm, Y = 3 mm, Z = 4 mm - X,Y,Z resolution < 200nm	**APH-15**	
	Optical High-Resolution Brightfield Microscope - Sample inspection with < 0.8 µm spatial resolution - Ca. 0.75 mm field of view diagonal - 5 Mpixel high-speed CCD-camera	**OBM-5**	
	Standard AFM modes supported - Intermittent contact mode & contact-mode - Mechanical topography & Phase Imaging, Error-signal - Photothermal Expansion mode (PTE)* * Not available in the US	**SAM-1**	

	AFM-Tip Illumination & Light Collection Unit (s-SNOM) - Patented parabolic mirror design for focusing & collection of light - Standard optical aperture NA = 0.39 - Motorized XYZ-positioner of parabolic mirror for precise focusing - Mirror positioning ranges: X,Y,Z = 4 mm, Resolution < 100nm - Accepts visible, infrared & even THz illumination wavelength - Patented dual-port design for two simultaneous light-beams on tip	**TICU-2** **PM-15**	**1**
	neaSNOM Microscope User-Kit	**NUK-2**	**1**
	Starter pack (10 pcs.) of neaspec certified AFM-tips	**CSP-10**	**1**
	Controller, User-PC, Software and Manual **neaSNOM Scan Controller and Optical Signal Processing Unit** - Synchronization of AFM mechanics with optical signals - Patented signal processing for optical background supression - Two custom ADC inputs for internal signal analysis - Two custom DAC outputs & two digital I/Os for external signal analysis	**CPCS** **NSC-4**	**1**
	neaSNOM User PC - Real-time signal visualization - 2 x 24" displays for user-friendly operation	**NPC-2**	
	neaSCAN Control and Data Acquisition Software - Control and scan software for AFM and optical signals - Optical imaging and spectroscopy software modules - Supports 1D, 2D and 3D scans	**NSCS-2**	
	Data Visualization and Analysis Software - Pre-installed state-of-art data visualization and analysis software - Suited for AFM topography data as well as optical near-field data	**DVS-1**	
	Hard & software manual incl. technical specifications (English)	**DOC-2**	
	neaSNOM On-Site Installation (incl. free 2-day basic user training) - On-site installation & validation of performance by Neaspec engineer - 2-day basic user training for instant operation after installation	**SI-OS**	**1**

Upgrades and measurement modes for neaSNOM Microscope:

2	**Position Sensors for Motorized Parabolic Mirror Axes** - Enables alignment-free focusing of laser to AFM-tip - Enables automated one-click switch of imaging & spectroscopy mode	**PSPM-3**	**1**
3	**High NA Parabolic Mirror Objective** - Improves S/N-ratio by higher numerical aperture (NA=0.46) - Accepts visible, infrared & even THz illumination wavelength - Patented dual-port design for nanoscale imaging & spectroscopy - Recommended for light-source systems with low S/N-ratio	**PM-11**	**1**

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Near-Field Spectroscopy system (nano-FTIR) for neaSNOM:
- Optimized for near-field spectroscopy with the neaSNOM microscope
- Interferometric design (simultaneous detection of refractive index and absorbance)
- Patented background free optical detection technology
- Near-field imaging by spectral average (depending on reference mirror position)
- Intensive pre-testing and on site performance validation
- NeaSCAN spectroscopy hard and software modules included
- On-site integration with neaSNOM microscope
- Intensive on-site user training after installation

Near-Field Illumination Units:

0,1 – 3 THz and illumination Unit for THz-TDS spectroscopy:
- Guaranteed near field imaging and spectroscopy performance
- Typical frequency range: 0,1 – 3 THz
- Based on fs-laser sources
- Expected range for near field spectra: 0,5 – 2 THz
- Conventional (far-field) spectroscopy possible
- Includes integration with neaSNOM near field microscope
- Includes additional set of THz emitter/detectors with mounts for (f.e.) coupling to a cryo stage
- Starter pack of optimized near field probes for THz spectral range

Ultrafast nano-FTIR for pump-probe experiments
Upgrade: THz pump-probe option
- Includes additional delay line and synchronized software control for pump-probe
- Free space coupled optical output at 780 nm with more than 140 mW power (ELMA mounted on optical table next to neaSNOM)
- Customized fiber patch cord for temporal overlap of pump probe pulses

Celkem cena nabízené sestavy bez DPH	11 485 000 Kč
DPH 21%	2 411 850 Kč
Celkem cena nabízené sestavy včetně DPH 21%	13 896 850 Kč

Important Notes: THz pump probe option includes related hard and software functionalities, but not demonstrated measurements, optical coupling of synchronized pump beam is not included

Environmental requirements

Location:
- Recommended placement: basement or ground floor
- Recommended: a light switch close to the operator
- Vibration Isolation Workstation with steel support frame:
  Minimum entrance width of 125 cm required (for the frame of optical table)

Temperature & Air condition:
- Standard 2D scanning mode: temperature fluctuations should be optimally kept below ± 0.5 degree Celsius
- Single spot measurements over longer period of time (≥20 min.): temperature fluctuations should be optimally kept below ± 0.1 degree Celsius
- For optimal performance, keep system away from air convection due to air condition or upgrade with Neaspec acoustic enclosure

Humidity:
- Optimal working conditions: 40-50 %

Vibrations:
- Required: installation of neaSNOM system on the floating optical table
- Vibration level: below 1 nm PP, measured on the optical table in 20Hz - 2kHz band

Acoustic & Electromagnetic Fields:
- Required: installation of the neaSNOM system away from strong magnetic fields (e.g. NMR systems or similar)
- Required: acoustic noise level < 40dB
- For higher noise levels & optimal performance, upgrade with neaspec acoustic enclosure

Se srdečným pozdravem,
Yours sincerely.

[redacted]

Za Nicolet CZ s.r.o.
Dr. Ján Pásztor
Jednatel
[redacted]

www.nicoletcz.cz

neaSNOM-THz selected Peer Reviewed Publications

- Hyperspectral time-domain terahertz nanoimaging, Neda Alsadar Aghamiri, Florian Huth, Andreas Huber, Alireza Fali, reiner Hillenbrand and Yohannes Abate, Optics Express, Just accepted manuscript (2019)
- Probes for ultra-sensitive THz nanoscopy, C. Maissen, S. Chen, E. Nikulina, A. Govyadinov and R. Hillenbrand, ACS Photonics, Just accepted manuscript (2019)
- 'All-electronic terahertz nanoscopy', C. Liewald et al. Optica 5, 159 (2018);
- 'Sub-wavelength near field imaging techniques at terahertz frequencies', M. C. Giordano et al. Proc. SPIE 10540, Quantum Sensing and Nano Electronics and Photonics XV, 105400N (2018);
- 'Nanoscale Terahertz Emission Spectroscopy', P. Klarskov et al. Advanced Photonics (2017);
- Terahertz Nanofocusing with Cantilevered Terahertz-Resonant Antenna Tips, S. Mastel et al., Nano Letters 17, 6526 (2017);
- Acoustic terahertz graphene plasmons revealed by photocurrent nanoscopy, P. Alonso-Gonzalez et al., Nature Nanotechn. 12, s 31–35 (2017);
- The 2017 terahertz science and technology roadmap, S. S. Dhillon et al. J. Phys. D: Appl. Phys. 50, 043001 (2017);
- Ultrafast multi-terahertz nano-spectroscopy with sub-cycle temporal resolution, M. Eisele et al., Nature Photonics 8, 841 (2014);
- Nanoscale terahertz spectroscopy, H. Shigekawa et al. Nature Photonics 8, 815-817 (2014);
- Review of Near-Field Terahertz Measurement. Methods and Their Applications. How to Achieve Sub-Wavelength Resolution at THz Frequencies, A.J. L. Adam, J Infrared Milli Terahz Waves 2909 (2011);
- Nanoscale Conductivity Contrast by Scattering-Type Near-Field Optical Microscopy in the Visible, Infrared and THz Domains, F. Keilmann, J Infrared Milli Terahz Waves 30: 1255 (2009);
- Microscopy: A terahertz nanoscope, P. Planken, Nature, 456, 7221 (2008);
- Terahertz Near-Field Nanoscopy of Mobile Carriers in Single Semiconductor Nanodevices, A. J. Huber et al., Nano Letters 8, 3766 (2008);
- Spectroscopic THz near-field microscope, H.-G. von Ribbeck et al. Opt. Express 16, 3430-3438 (2008);
- Spectroscopic near-field microscopy using frequency combs in the mid-infrared, M. Brehm et al. Opt. Express 14, 11222 (2006);

neaSNOM Selected Peer Reviewed Publications about Photocurrent correlative measurements

- Thermoelectric detection of propagating plasmons in graphene, M. B. Lundeberg et al., **Nature Mater.,** Advance Online Publication (2017).
- Acoustic terahertz graphene plasmons revealed by photocurrent nanoscopy, P. Alonso-Gonzalez et al., **Nature Nanotechn.** Advance Online Publication (2017).
- Near-field photocurrent nanoscopy on bare and encapsulated graphene, A. Woessner et al., **Nature Commun.** 7, Advance Online Publication (2016).

Selection of neaSNOM publications including interferometric Amplitude and Phase resolved imaging

- 'Infrared hyperbolic metasurface based on nanostructured van der Waals materials', *P. Li, I. Dolado et al.* **Science** 359, 892–896;
- 'Boron nitride nanoresonators for phonon-enhanced molecular vibrational spectroscopy at the strong coupling limit', *M. Autore et al.* **Light: Science & Applications**;
- 'Probing optical anisotropy of nanometer-thin van der waals microcrystals by near-field imaging', *D. Hu et al.* **Nature Communications** 8, 1471;
- 'Macroscopic alignment and assembly of π-conjugated oligopeptides using colloidal microchannels', *B. Li, et al.* **ACS Appl. Mater.**;
- 'Propagating Plasmons in a Charge-Neutral Quantum Tunneling Transistor', *A. Woessner, et al.* **ACS Photonics;**
- 'Direct amplitude-phase near-field observation of higher-order anapole states', *V. A. Zenin, et al.* **Nano Letters**;
- 'Launching Phonon Polaritons by Natural Boron Nitride Wrinkles with Modifiable Dispersion by Dielectric Environments', *J, Duan, et al.* **Adv. Mater.** 29, 170294;
- 'Plasmon Reflections by Topological Electronic Boundaries in Bilayer Graphene', *B.-Y. Jianget al.* **Nano Letters**;
- 'Mechanical Detection and Imaging of Hyperbolic Phonon Polaritons in Hexagonal Boron Nitride', *A. Ambrosio et al.* **ACS Nano** 11, 8741;
- 'Highly Efficient and Air-Stable Infrared Photodetector Based on 2D Layered Graphene–Black Phosphorus Heterostructure', *Y. Liu et al.* **ACS Appl. Mater. Interfaces** 9, 36137;
- 'Infrared Nanoimaging Reveals the Surface Metallic Plasmons in Topological Insulator', *J. Yuan et al.* **ACS Photonics**;
- 'Intrinsic Plasmon–Phonon Interactions in Highly Doped Graphene: A Near-Field Imaging Study', *F. J. Bezares et al.* **Nano Letters** 17 (10), 5908–5913;

- 'Oxygen impact on the electronic and vibrational properties of black phosphorus probed by synchrotron infrared nanospectroscopy', *D. Grasseschi et al.* **2D Mater.** 4, 035028;

- 'Porous Two-Dimensional Monolayer Metal–Organic Framework Material and Its Use for the Size-Selective Separation of Nanoparticles', *Y. Jiang, et al.* **ACS. Appl. Mater. Interfaces** 9, 28107;
- 'The Light-Induced Field-Effect Solar Cell Concept – Perovskite Nanoparticle Coating Introduces Polarization Enhancing Silicon Cell Efficiency', *Y. Wang et al.* **Advanced Materials** 29, 1606370;
- 'Electrical 2π phase control of infrared light in a 350-nm footprint using graphene plasmons', *A. Woessner et al.* **Nature Photonics** 11, 421-424;
- **'Nanoscale Terahertz Emission Spectroscopy', *P. Klarskov et al.* Advanced Photonics;**
- **Terahertz Nanofocusing with Cantilevered Terahertz-Resonant Antenna Tips, *S. Mastel et al.*, Nano Letters 17, 6526;**
- Acoustic terahertz graphene plasmons revealed by photocurrent nanoscopy, *P. Alonso-Gonzalez et al.*, **Nature Nanotechn.** 12, s 31–35;
- 'Phonon-Polaritonic Bowtie Nanoantennas: Controlling Infrared Thermal Radiation at the Nanoscale', *T. Wang et al.* **ACS Photonics** 4, 1753;
- 'Imaging metal-like monoclinic phase stabilized by surface coordination effect in vanadium dioxide nanobeam', Z. Li et al. **Nature Communications** 8, 15561;
- 'Tuning quantum nonlocal effects in graphene plasmonics', *M. B. Lundeberg et al.* **Science**;
- 'Nanoimaging of resonating hyperbolic polaritons in linear boron nitride antennas', *F.J. Alfaro-Mozaz, et al.* 8, 15624;
- 'Imaging exciton–polariton transport in MoSe2 waveguides', *F. Hu et al.* **Nature Photonics** 11, 356-360;
- 'Extraordinary linear dynamic range in laser-defined functionalized graphene photodetectors', *A. De Sanctis et al.* **Science Advances** 3, e1602617;
- 'White Light Generation and Anisotropic Damage in Gold Films near Percolation Threshold', S. *M. Novikov et al.* **ACS Photonics** 4, 1207-1215;
- 'Dual-Scattering Near-Field Microscope for Correlative Nanoimaging of SERS and Electromagnetic Hotspots', P. *Kusch et al.* **Nanoletters** 17 (4), 2667-2673
- 'Flexible, Transparent, and Free-Standing Silicon Nanowire SERS Platform for in Situ Food Inspection', *H. Cui et al.* **ACS Sensors**, 2 (3), 386–393;
- 'Hyperspectral infrared nanoimaging of organic samples based on Fourier transform infrared nanospectroscopy', *I. Amenabar et al.* **Nature Communications** 8, 14402;
- 'Direct Electrical Probing of Periodic Modulation of Zinc-Dopant Distributions in Planar Gallium Arsenide Nanowires', *W. Choi et al.* **ACS Nano** 11 (2), 1530-1539;
- 'Bridged Bowtie Aperture Antenna for Producing an Electromagnetic Hot Spot', *Y. Chen et al.* **ACS Photonics** 4, 567-575;
- 'Femtosecond photo-switching of interface polaritons in black phosphorus heterostructures', *M. A. Huber et al.* **Nature Nanotechnology** 12, 207-211;
- Optical Nanoimaging of Hyperbolic Surface Polaritons at the Edges of van der Waals Materials *P. Li, I. Dolado et al.* **Nano Letters** 17, 228;
- 'Study of graphene plasmons in graphene–MoS2 heterostructures for optoelectronic integrated devices', *R. Liu et al.* **Nanoscale**, 9, 208;
- 'Ultra-confined plasmonic hotspots inside graphene nanobubbles', *Z. Fei et al.* **Nano Letters**;
- 'Acoustic terahertz graphene plasmons revealed by photocurrent nanoscopy', *P. Alonso-González et al.* **Nature Nanotechnology**;

- 'Tailorable reflection of surface plasmons in defect engineered graphene', *W. Luo et al.* **2D Materials**, 3 045001;
- 'Thermoelectric detection and imaging of propagating graphene plasmons', *M. B. Lundeberg et al.* **Nature Materials**;
- 'Molybdenum Nanoscrews: A Novel Non-coinage-Metal Substrate for Surface-Enhanced Raman Scattering', *D. An et al.* **Nano-Micro Letters** 9: 2;
- 'Nanoscopy of Phase Separation in InxGa1–xN Alloys', *Y. Abate et al.* **ACS Appl. Mater. Interfaces**, 8 (35), pp 23160–23166;
- 'Chemically-doped graphene with improved surface plasmon characteristics: an optical near-field study', *Z. Zheng et al.* **Nanoscale**;
- 'Reversible Structural Swell-Shrink and Recoverable Optical Properties in Hybrid Inorganic-Organic Perovskite', *Y. Zhang et al.* **ACS Nano**;
- 'Gate-Tunable Spatial Modulation of Localized Plasmon Resonances', *A. Arcangeli et al.* **Nano Letters** 16 (9), 5688-5693;
- 'Nanofocusing of Hyperbolic Phonon Polaritons in a Tapered Boron Nitride Slab', *A. Y. Nikitin et al.* **ACS Photonics**;
- 'Reversible optical switching of highly confined phonon–polaritons with an ultrathin phase-change material', *P. Li et al.* **Nature Materials**;
- 'Nanoscopy of Black Phosphorus Degradation', *S. Gamage et al.* **Advanced Materials**;
- 'Interfaces Imaging of Anomalous Internal Reflections of Hyperbolic Phonon-Polaritons in Hexagonal Boron Nitride', *A. J. Giles et al.* **Nano Letters** 16(6), 3858-3865;
- 'Ultrafast optical switching of infrared plasmon polaritons in high-mobility graphene', *G. X. Ni et al.* **Nature Photonics** 10, 244–247;
- 'Real-space mapping of tailored sheet and edge plasmons in graphene nanoresonators', *A. Y. Nikitin et al.* **Nature Photonics** 10, 239–243;
- 'Near-field photocurrent nanoscopy on bare and encapsulated graphene', *A. Woessner et al.* **Nature Communications** 7, 1078;
- 'Far-Field Spectroscopy and Near-Field Optical Imaging of Coupled Plasmon–Phonon Polaritons in 2D van der Waals Heterostructures', *X. Yang et al.* **Advanced Materials** 28, Issue 15, pp. 2931–2938;
- 'Harnessing a Quantum Design Approach for Making Low-Loss Superlenses', *A. O. Bak et al.* **Nano Letters**;
- 'Ultrafast Mid-Infrared Nanoscopy of Strained Vanadium Dioxide Nanobeams', *M. A. Huber et al.* **Nano Letters**;

V Praze 08. 07. 2019

[redacted]

Technical Specifications Tests

neaSNOM Specifications and Site Acceptance Test

Dr. Sergiu Amarie
neaspec
10th Aug 2017

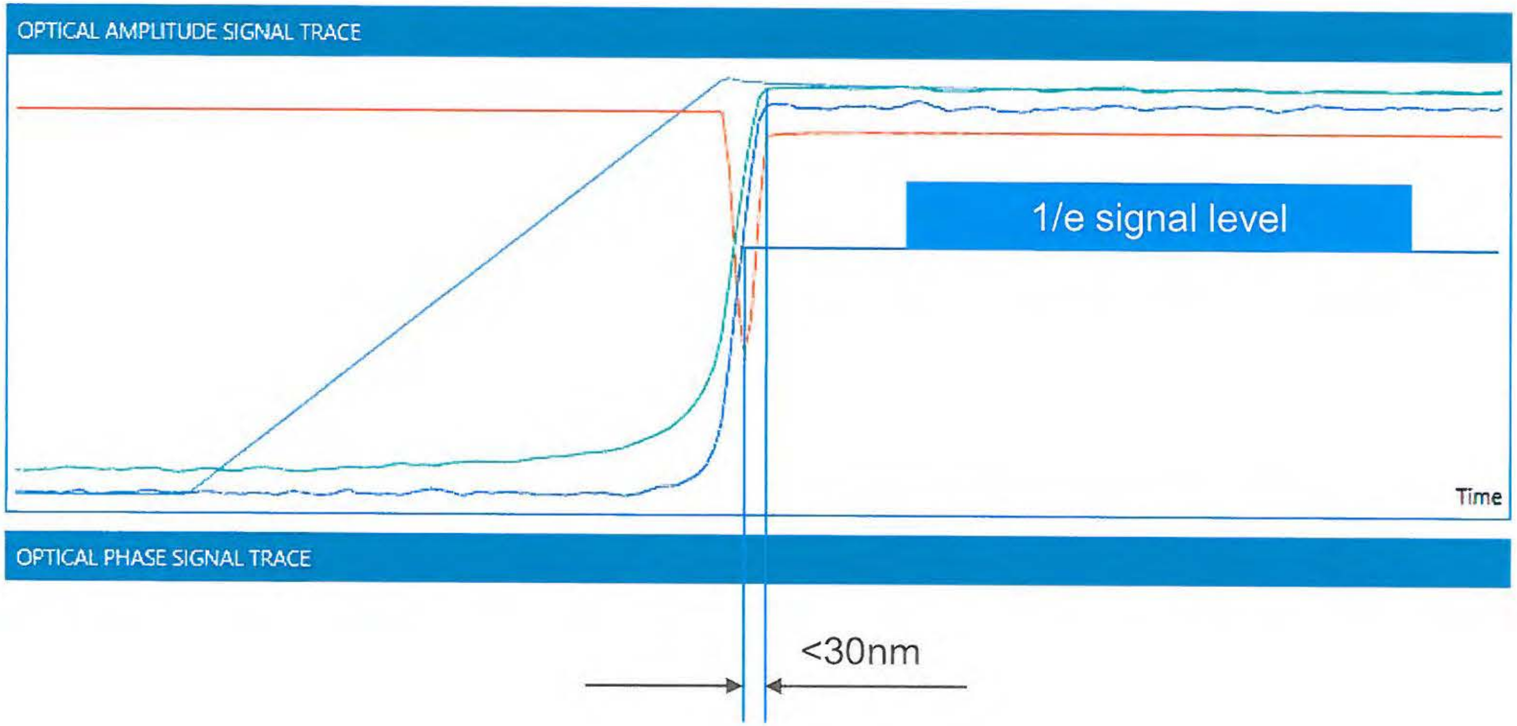
see the nanoworld
neaspec

2.1 THz-TDS near-field spectroscopy

Specification

Test 2.1.1 - Verification of nanoscale (<30nm) confinement of optical tip-sample interaction at higher harmonic optical signal by vertical scan (approach curves).

Performed Tests

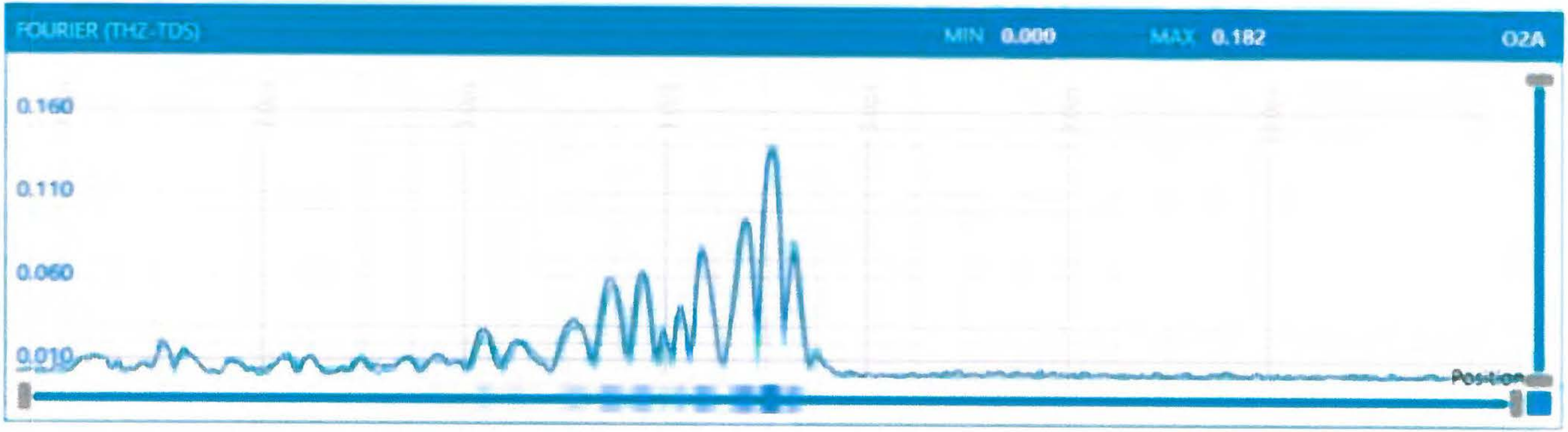


2.1 THz-TDS near-field spectroscopy

Specification

Test 2.1.2 - - Measurement of THz pulse by neaSCAN software on Au surface at different harmonics of tip oscillation frequency.

Performed Tests

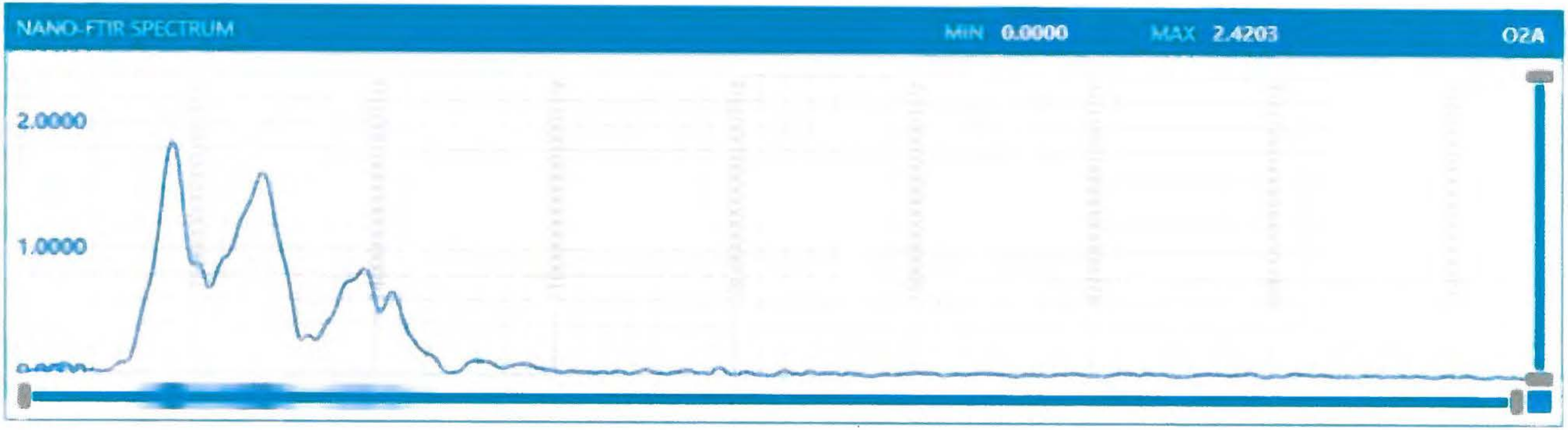


2.1 THz-TDS near-field spectroscopy

Specification

Test 2.1.3 - Measurement of THz near-field spectra by neaSCAN software on Au surface in amplitude and phase at different harmonics of tip oscillation frequency

Performed Tests

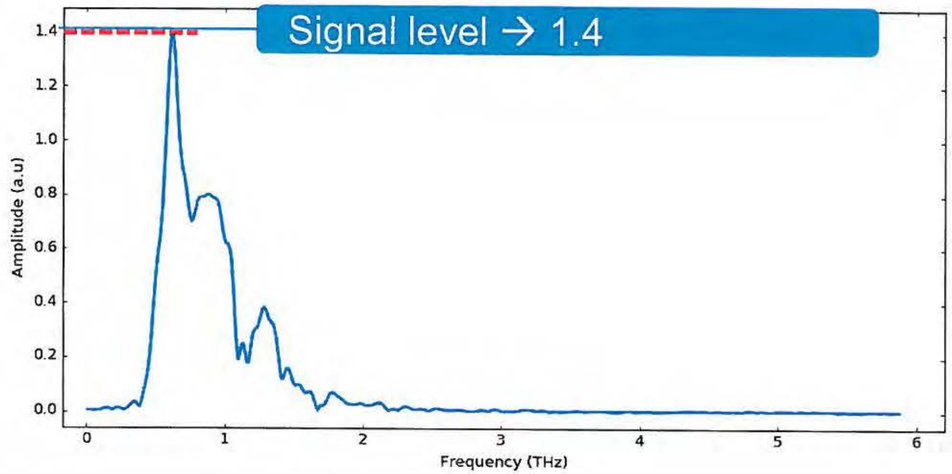


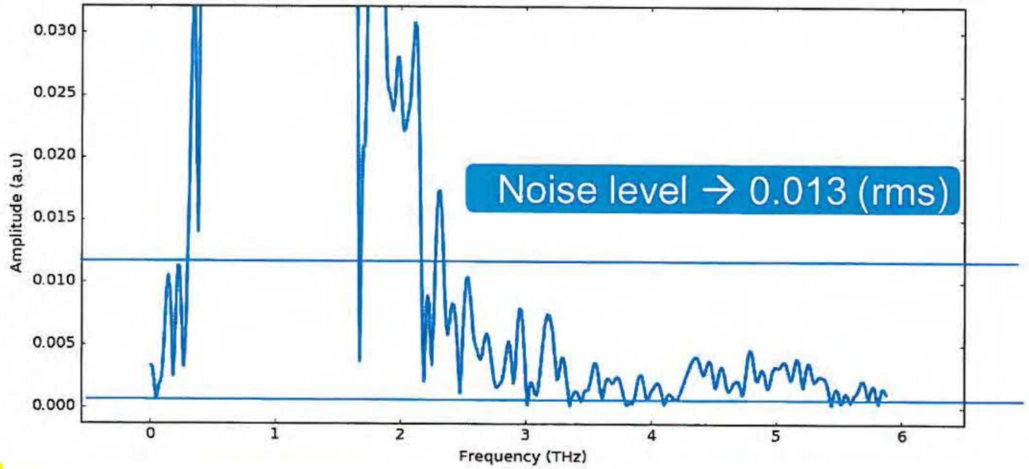
2.1 THz-TDS near-field spectroscopy

Specification

Test 2.1.4 - signal-to-noise of 100 recorded within 8 min on Au test-sample provided by neaspec

Performed Test	Test Result





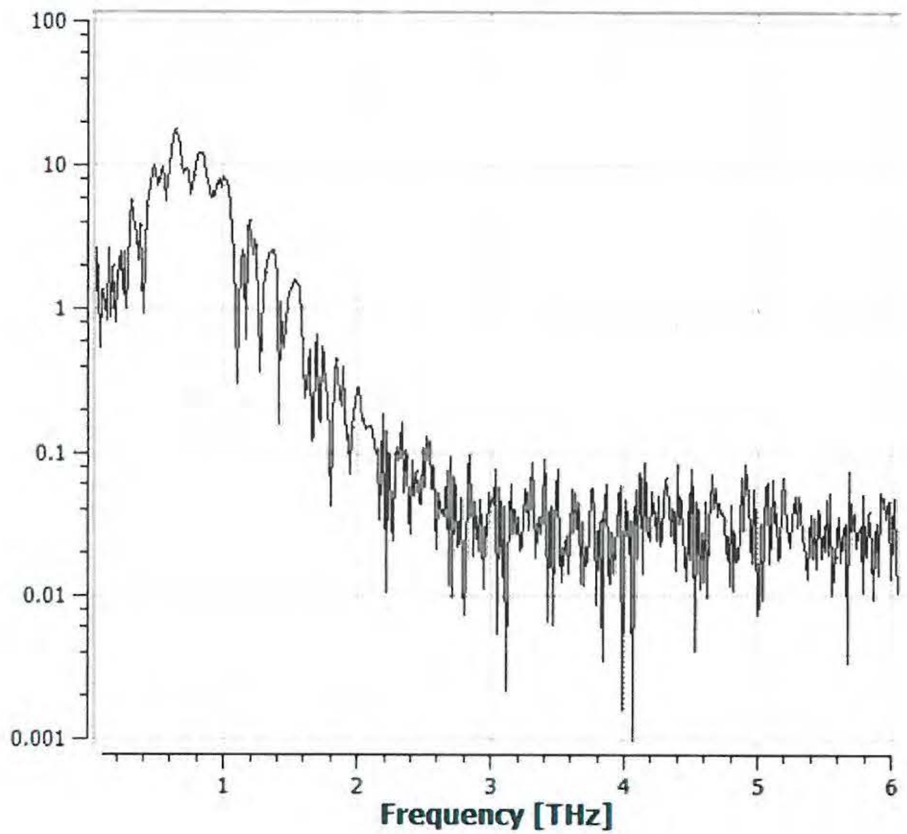
S/N = 1.4 / 0.012 = 116

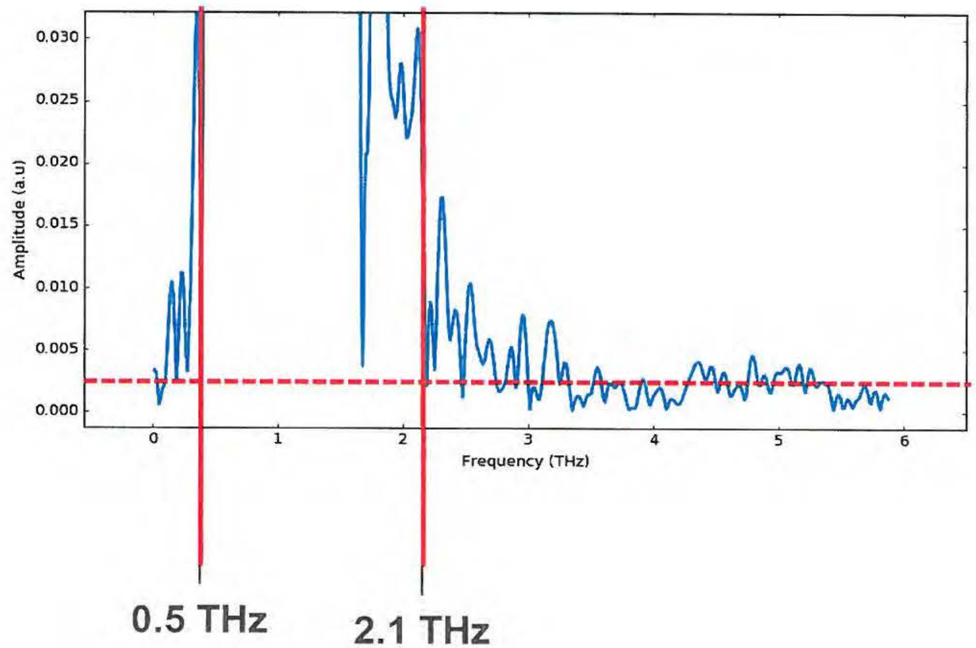
2.1 Spectral coverage 0.5-2.1 THz

Specification

Test 2.1.5 Demonstration of spectral coverage. Typichal frequency range 01.-3 THz for far-field module. Expected range of 0.5-2.1 THz for near-field applications.

Performed Tests	Test Result
Source spectral range = 0.1-3 THz	Near-field range = 0.5-2.1 THz

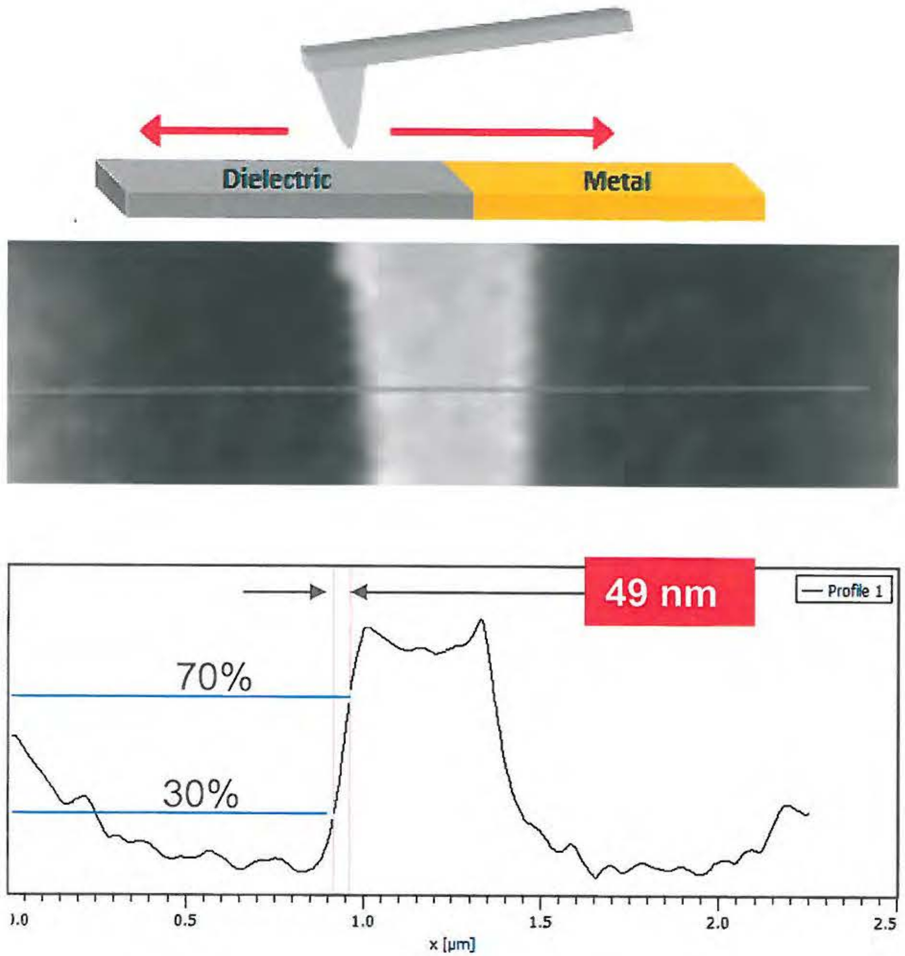




2.2 THz-TDS based near-field imaging

Specification

Test 2.2.1 - Verification of nanoscale spatial resolution (<50nm) test measured at the interface of two materials exhibiting THz dielectric contrast (e.g Au / SiC or Si / Doped Si)

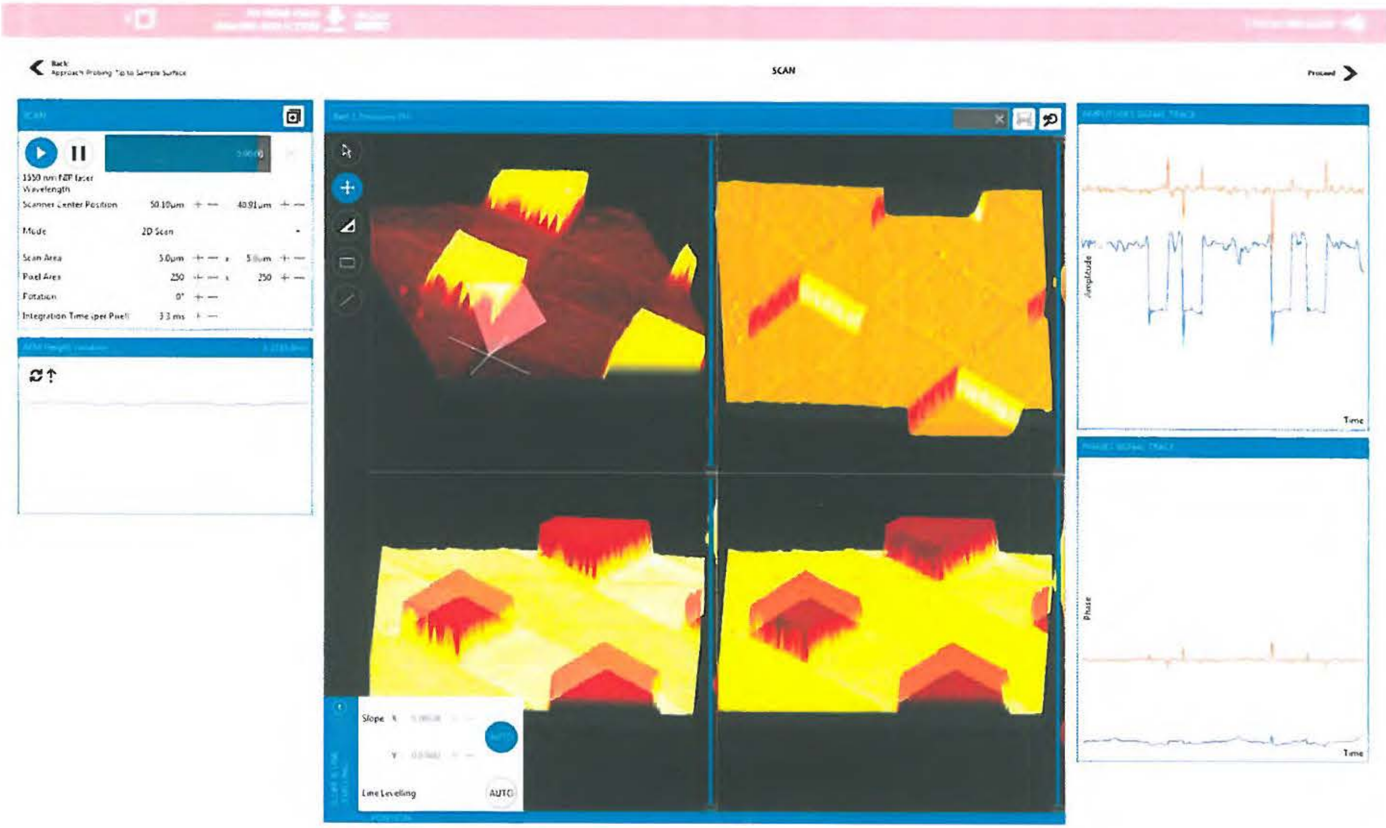
Performed Test	Test Result
	Lateral resolution < 50 nm

2.2 THz-TDS based near-field imaging

Specification

Test 2.2.2 - near-field imaging with integrated THz signal of Au/SiC test structure (integrated THz signal corresponds to signal at selected time delay of THz pulse)

Performed Tests

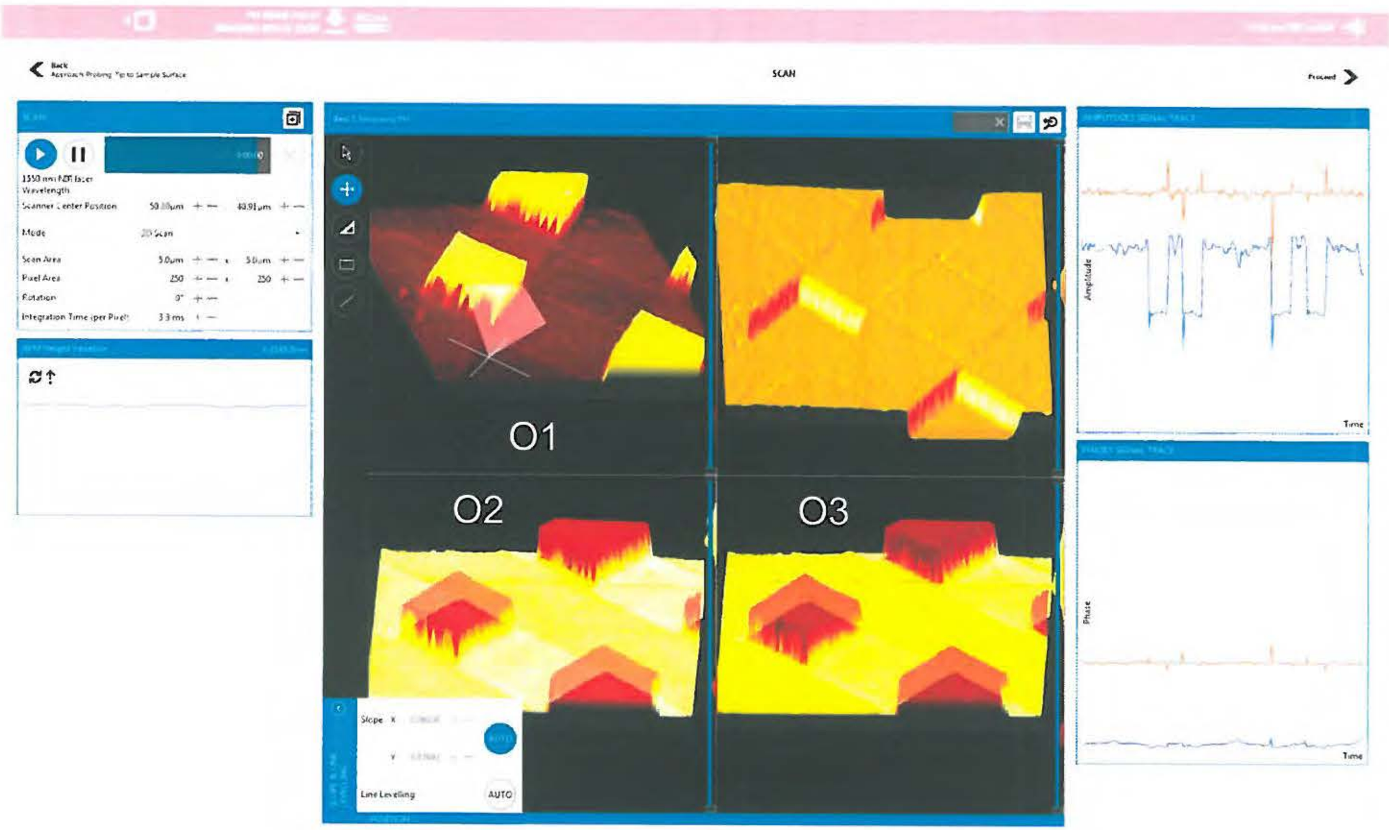


2.2 THz-TDS based near-field imaging

Specification

Test 2.2.3 - Simultaneous measurement of integrated THz near-field signal at different harmonics of tip oscillation frequency.

Performed Tests



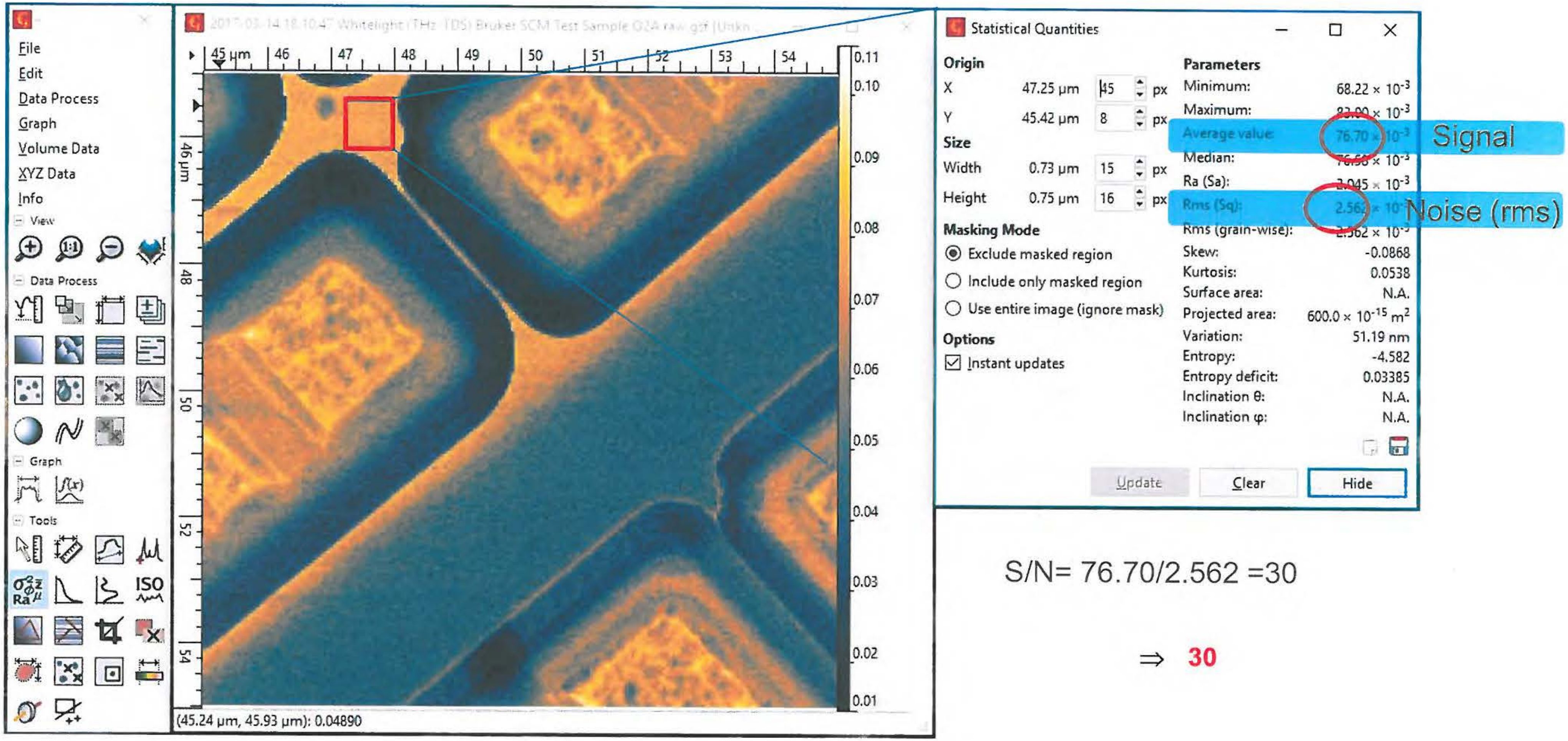
2.2 THz-TDS based near-field imaging

Specification

Test 2.2.4 Spectral Integrated Imaging* tests performed on SRAM sample with signal-to-noise S/N of at least 40. Measurement time 5 min. Spectral-range 0.5 - 2.2 THz.

Performed Tests	Test Result

THz-TDS Spectral Integrated Image

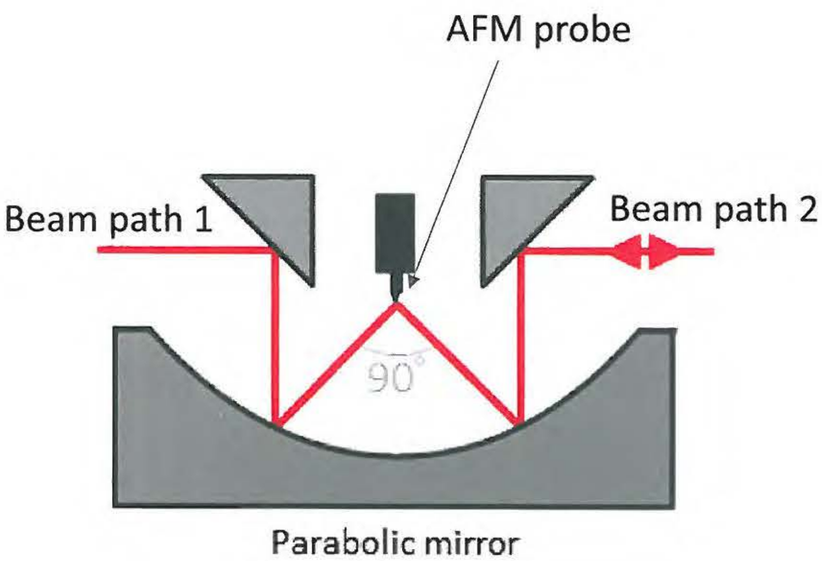


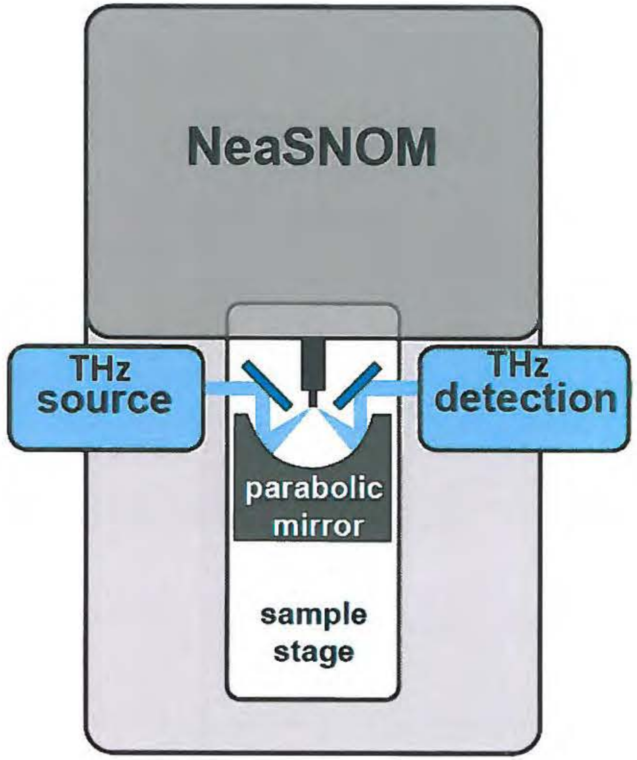
S/N= 76.70/2.562 =30

⇒ **30**

Tender support information

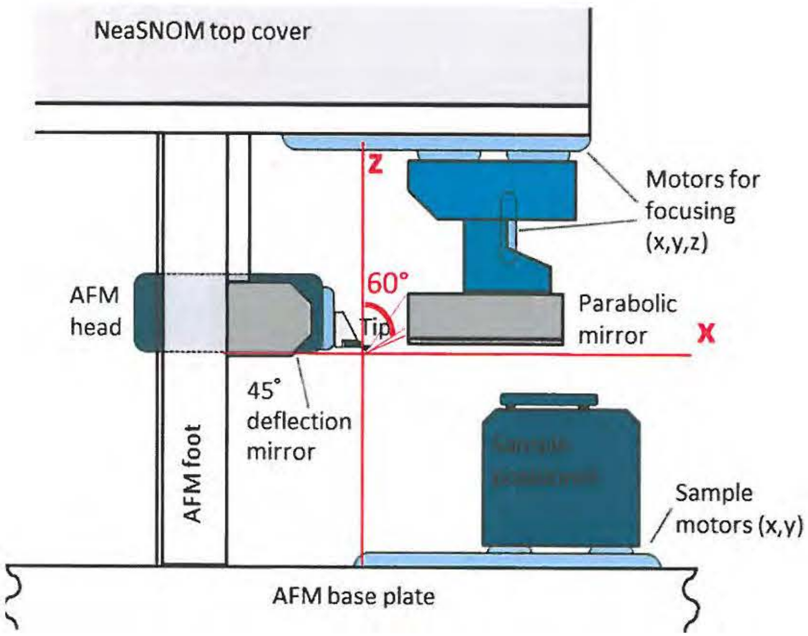
1. – The dual bam path configuration of the neaSNOM system is the ideal support for the THz-TDS illumination/detection unit



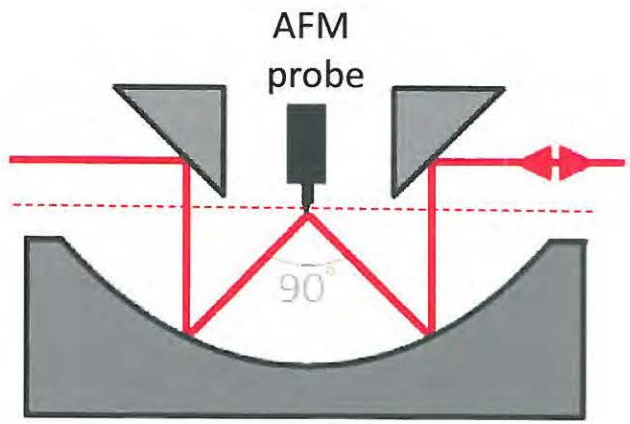


2. – Sketches of the neaSNOM side view and top view illuminations show the ultra-high optical access to AFM tip (180° horizontal, 60° vertical).

Side view Illumination



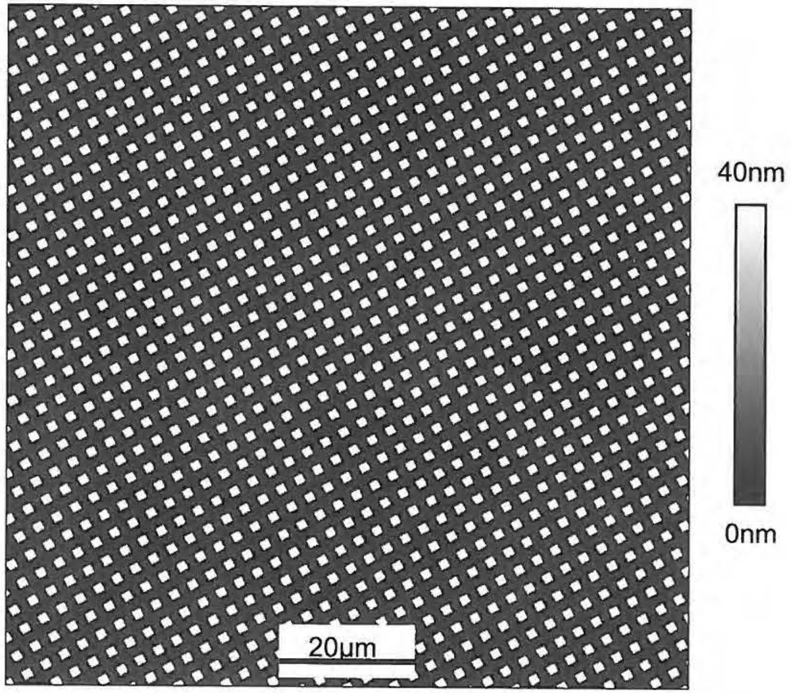
Top view Illumination



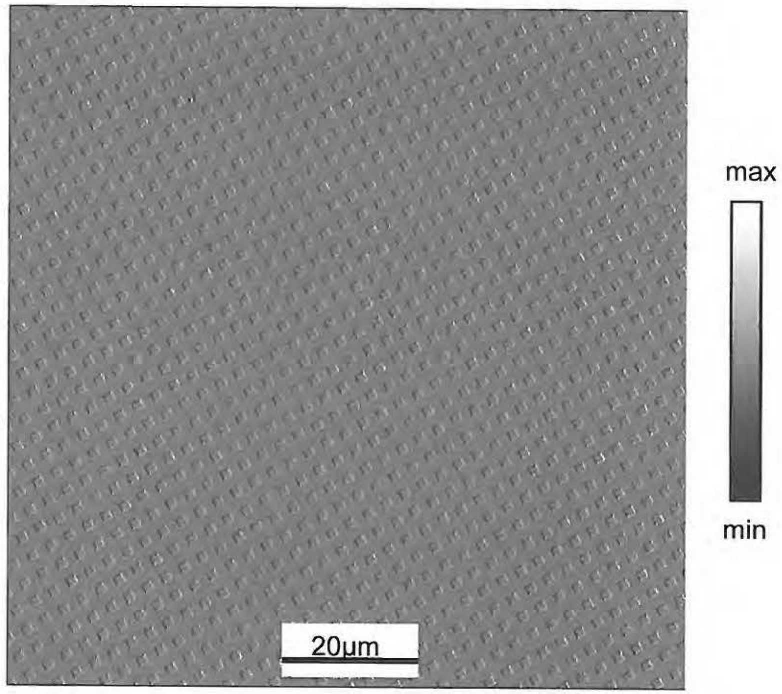
3. – Maximum scanning size: 100 x 100 μm^2

- 100x100µm image of test grating
- imaging parameters: 500x500pix, pixel time 5ms.

topography

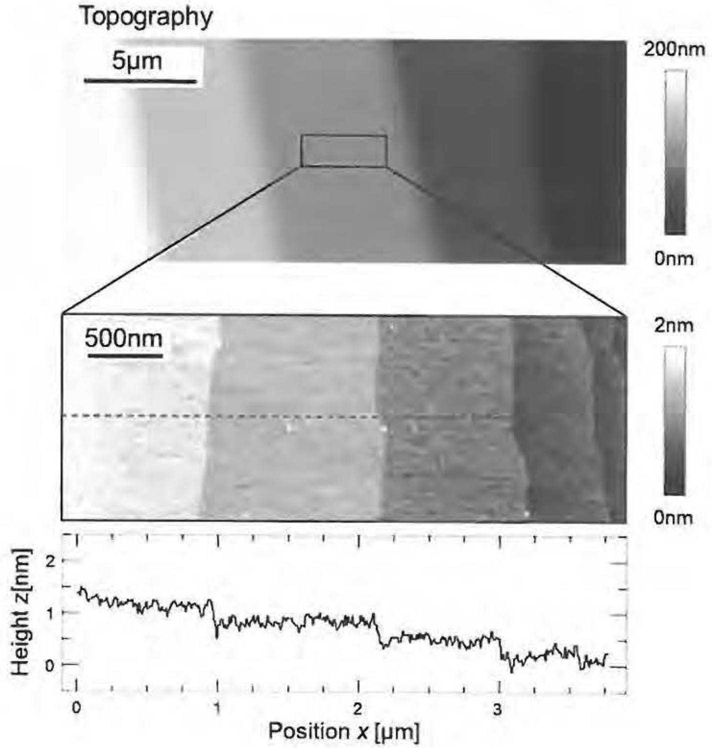


cantilever oscillation amplitude (M1 signal)



4. –Noise-limited z-resolution (RMS) test

The figure below shows topographic measurements on a Si test sample. As can be seen below the mono-atomic steps on the Si surface can easily be resolved and the measured RMS noise on the terraces agrees excellent to the sample specifications.



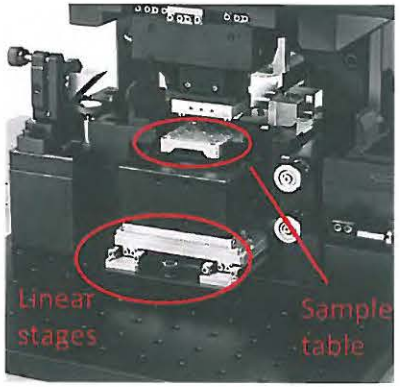
Sample details:

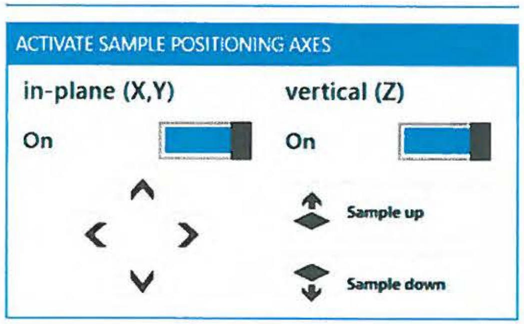
- Si echeloned test pattern (STEPP sample of NT-MDT)
- Surface exhibits larger terraces with step heights of approx. 30-50nm (upper image)
- Terraces contain single monoatomic steps with a height of 0.314nm (lower image)
- Specified average roughness of area without steps approx. 0.06nm

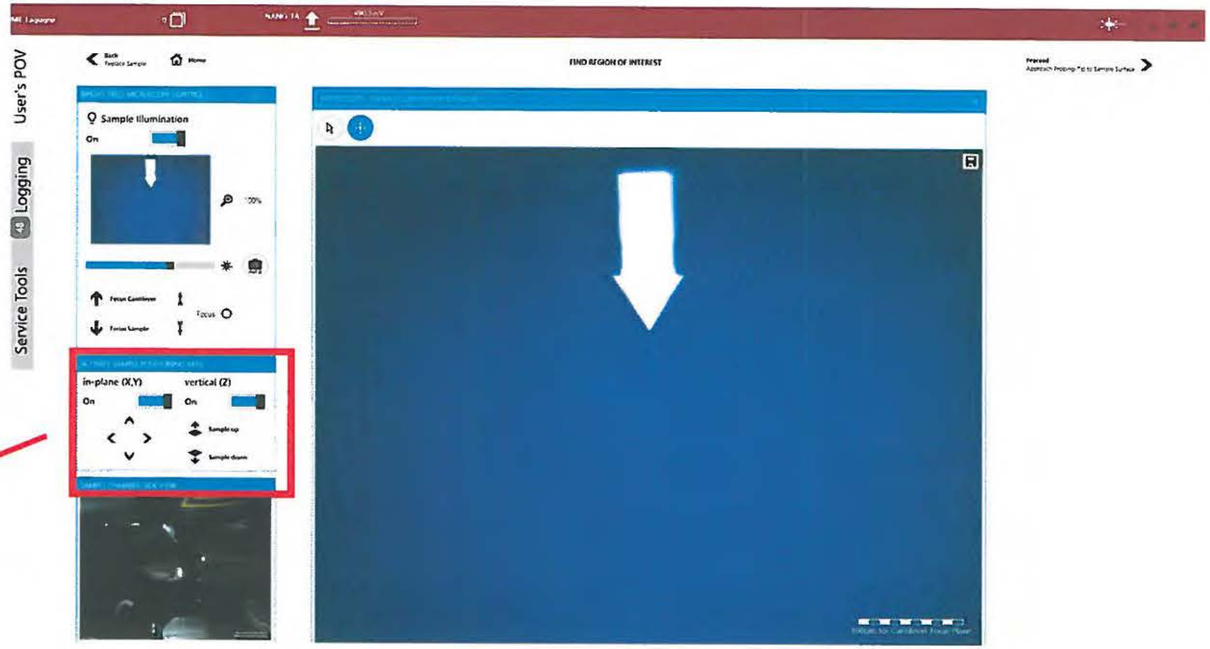
Results:

- Imaged at ambient conditions
- No signal analysis was applied, e.g. filtering (only line correction)
- Profile of single scan line (no averaging)
- Noise on flat area ≈0.072nm (RMS)

5. – Sample position stage is motorized and computer controlled. Software screenshot from the 'Find region of interest' window is provided below.

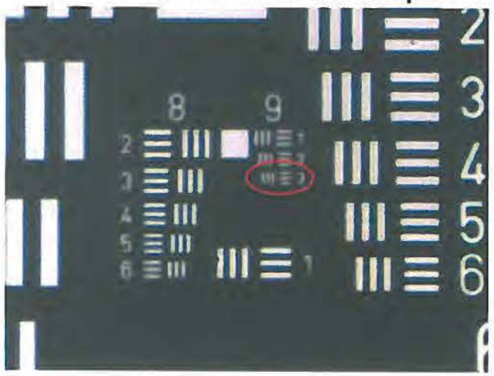






6. – Far-field resolution of the integrated optical microscope < 0.8µm

USAF 1951-test sample

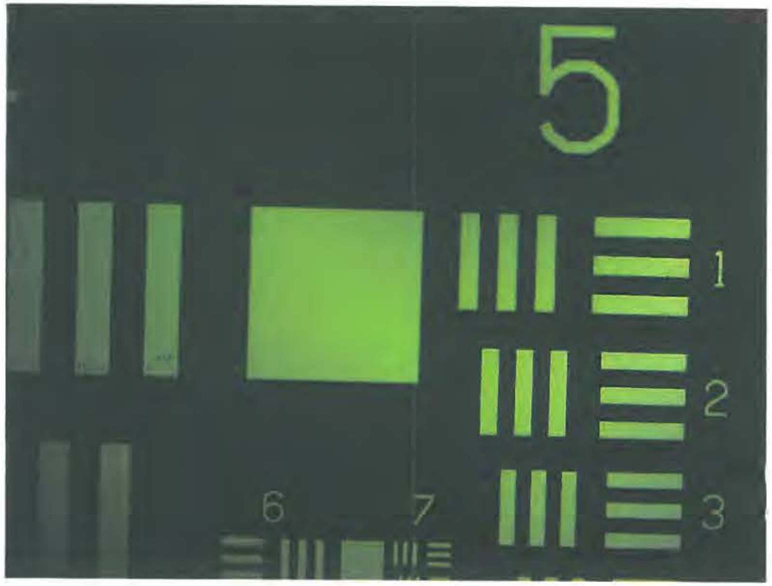


- USAF 1951 resolving power test target
- smallest line structure: 1/645.0mm pitch (element 9-3)
- smallest structure size of ≈0.77µm resolved

Number of Line Pairs / mm in USAF Resolving Power Test Target 1951											
	Group Number										
Element	**-2**	**-1**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	0.250	0.500	1.00	2.00	4.00	8.00	16.00	32.0	64.0	128.0	256.0	512.0
2	0.280	0.561	1.12	2.24	4.49	8.98	17.95	36.0	71.8	144.0	287.0	575.0
3	0.315	0.630	1.26	2.52	5.04	10.10	20.16	40.3	80.6	161.0	323.0	645.0
4	0.353	0.707	1.41	2.83	5.66	11.30	22.62	45.3	90.5	181.0	362.0	-----
5	0.397	0.793	1.59	3.17	6.35	12.70	25.39	50.8	102.0	203.0	406.0	-----
6	0.445	0.891	1.78	3.56	7.13	14.30	28.50	57.0	114.0	228.0	456.0	-----

7. – Max. field-of view of integrated optical microscope ≈ 0.8mm

- USAF 1951 resolving power test target
- structure size of element 5-1: 1/32mm pitch
- max. diagonal field-of-view of ≈ 0.8mm



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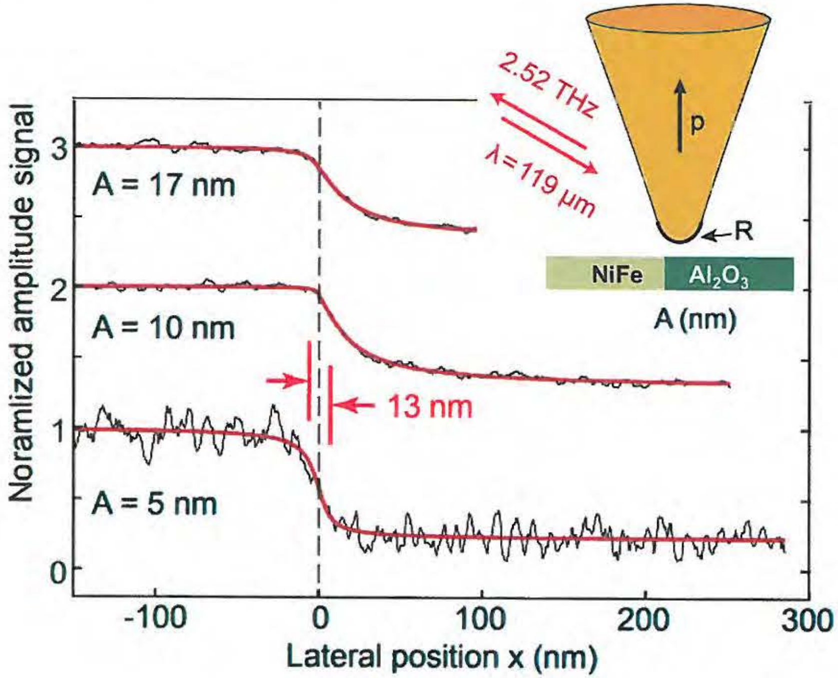
World record in THz s-SNOM: 13 nm spatial resolution



- THz image contrast (CW) obtained on HDD head shows **strong material contrast between metal and oxide**
- Line profile evaluation **demonstrates spatial resolution down to 13 nm (~λ/9000)**

neaSNOM demonstrates world record resolution of 13 nm at THz frequencies

C. Maissen et al., *ACS Phot.* **6**, 1279 (2019)