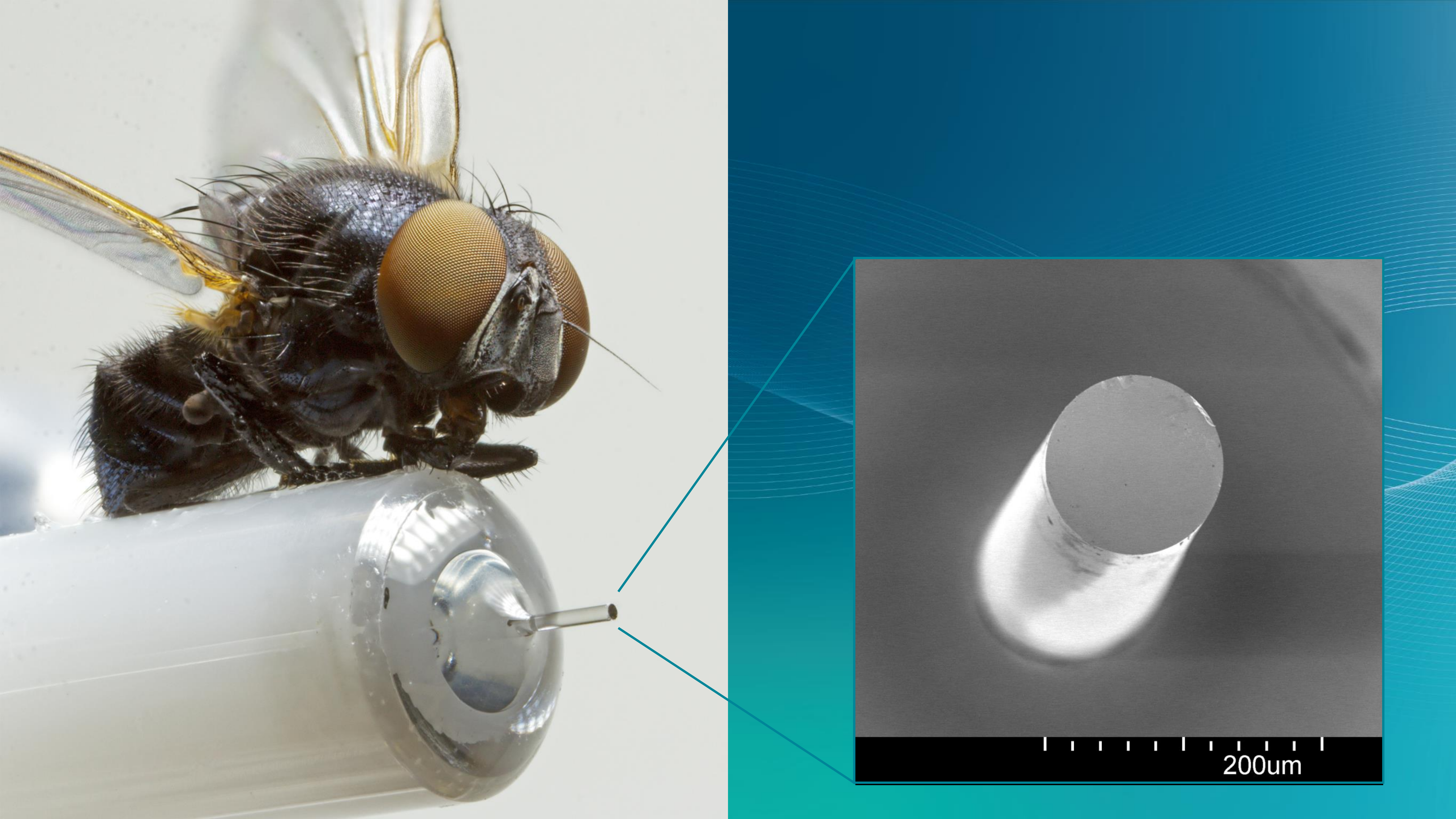
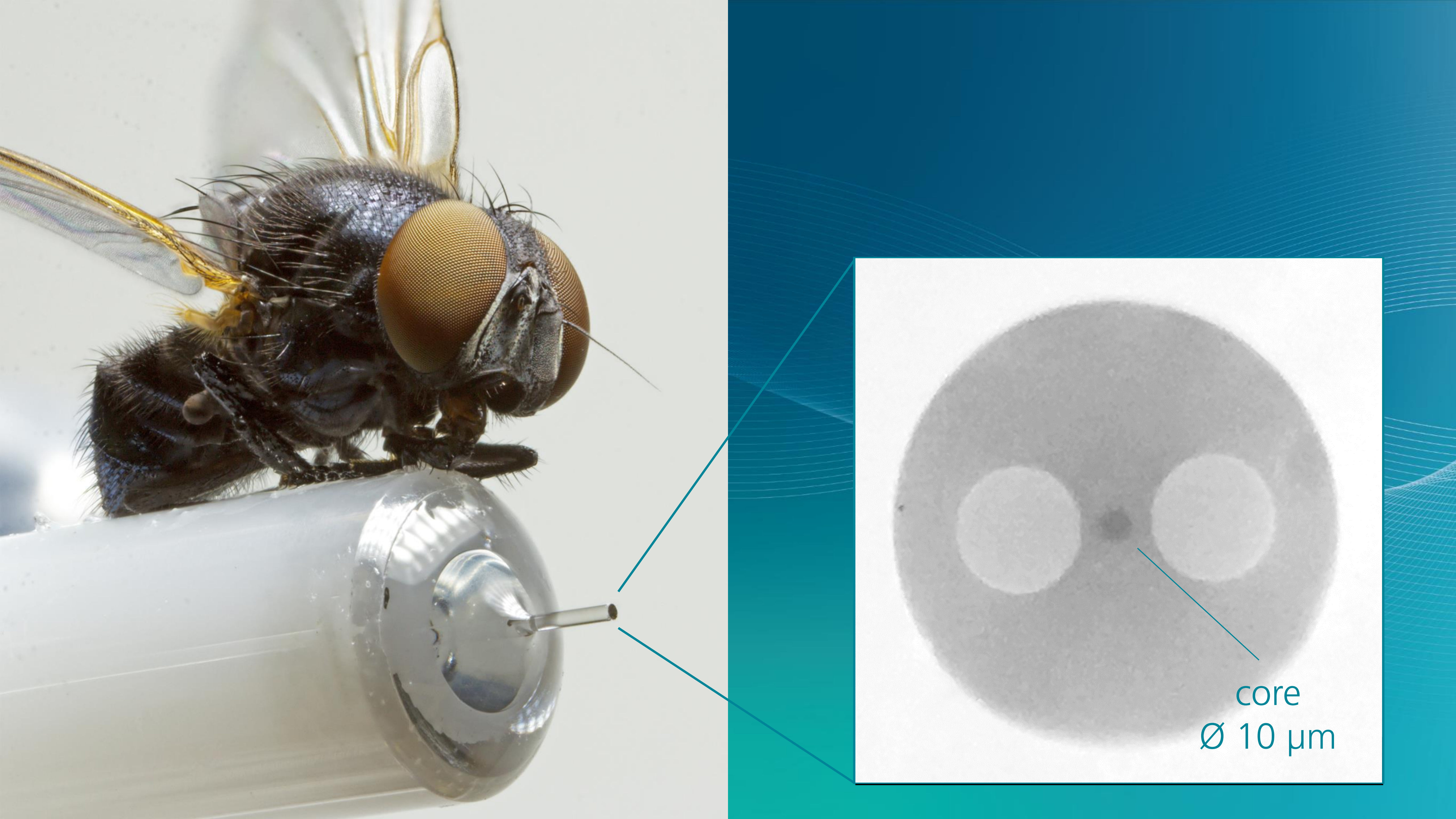
F. Paries, N. Tiercelin, G. Lezier,
M. Vanwolleghem, F. Selz, M.-A. Syskaki,
F. Kammerbauer, G. Jakob, M. Jourdan, M. Kläui,
Z. Kaspar, T. Kampfrath, T.S. Seifert,
G. von Freymann, and D. Molter

Fiber-tip Spintronic Terahertz Emitters


200um



core
Ø 10 µm

Is it possible to realize
Fiber-tip Spintronic Terahertz Emitters?

And if, what are
possible applications?

The fabrication consists of four processes: gluing, polishing, cleaning, and sputtering.

Gluing → Polishing → Cleaning → Sputtering

Many different fiber-tip-STE designs are possible.

Fiber material

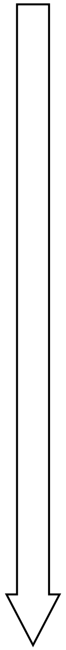
doped quartz glasses

14 Si Metalloid	32 Ge Metalloid
8 O Nonmetal	9 F Hallogen
	5 B Metalloid

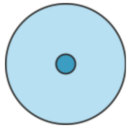
crystalline sapphire

13 Al Metalloid	8 O Nonmetal

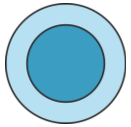
Core size



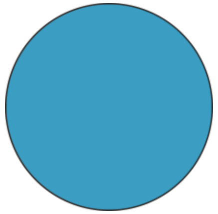
Ø 10 µm



Ø 100 µm



Ø 425 µm



Ferrule material

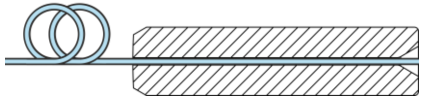
zirconia

stainless steel

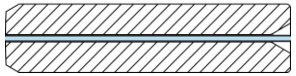
Connector type

bare fiber

pigtail



FC/PC



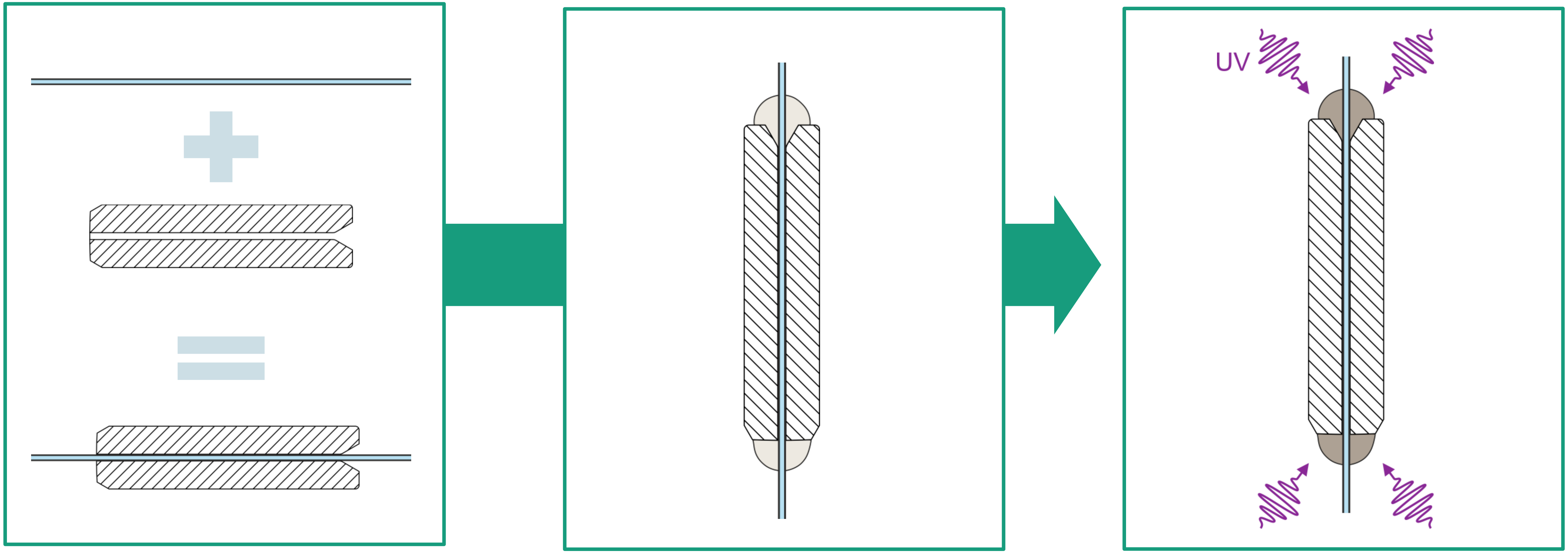
https://www.thorlabs.com/search/thorsearch.cfm?search=ferrules

The fiber is inserted into the ferrule and fixated using high-speed UV glue.

Fiber insertion

Glue placement

Glue hardening



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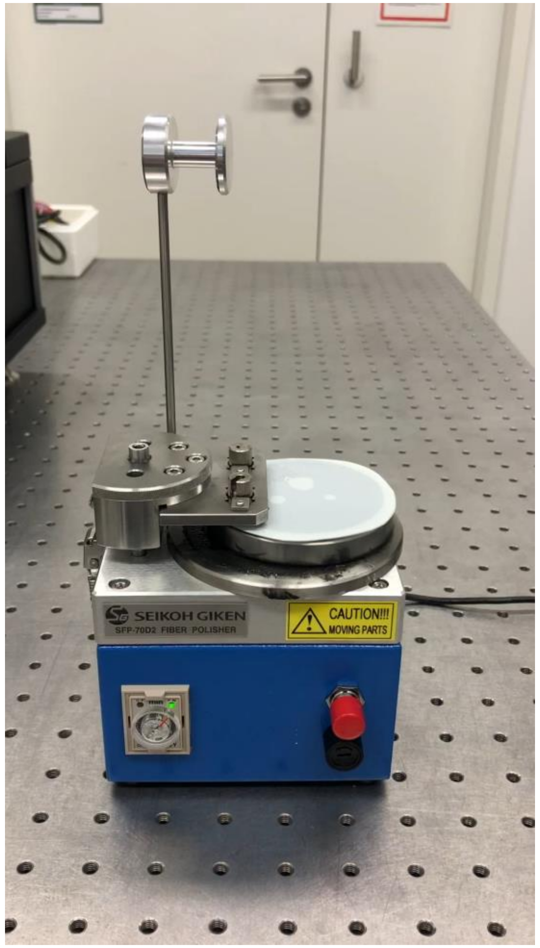
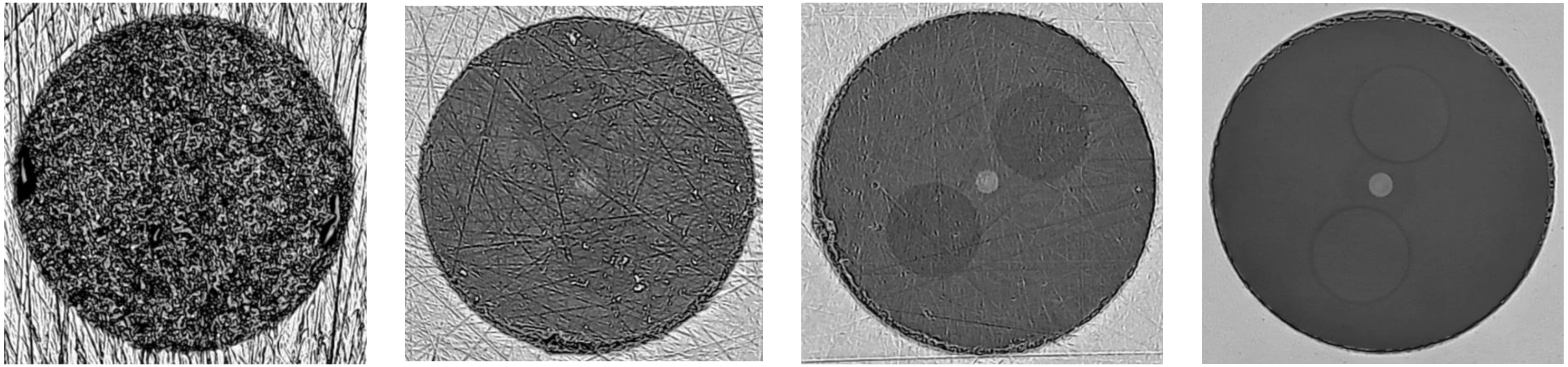
The end facets are polished via a sequence of polishing steps.



increasing surface quality



6 µm

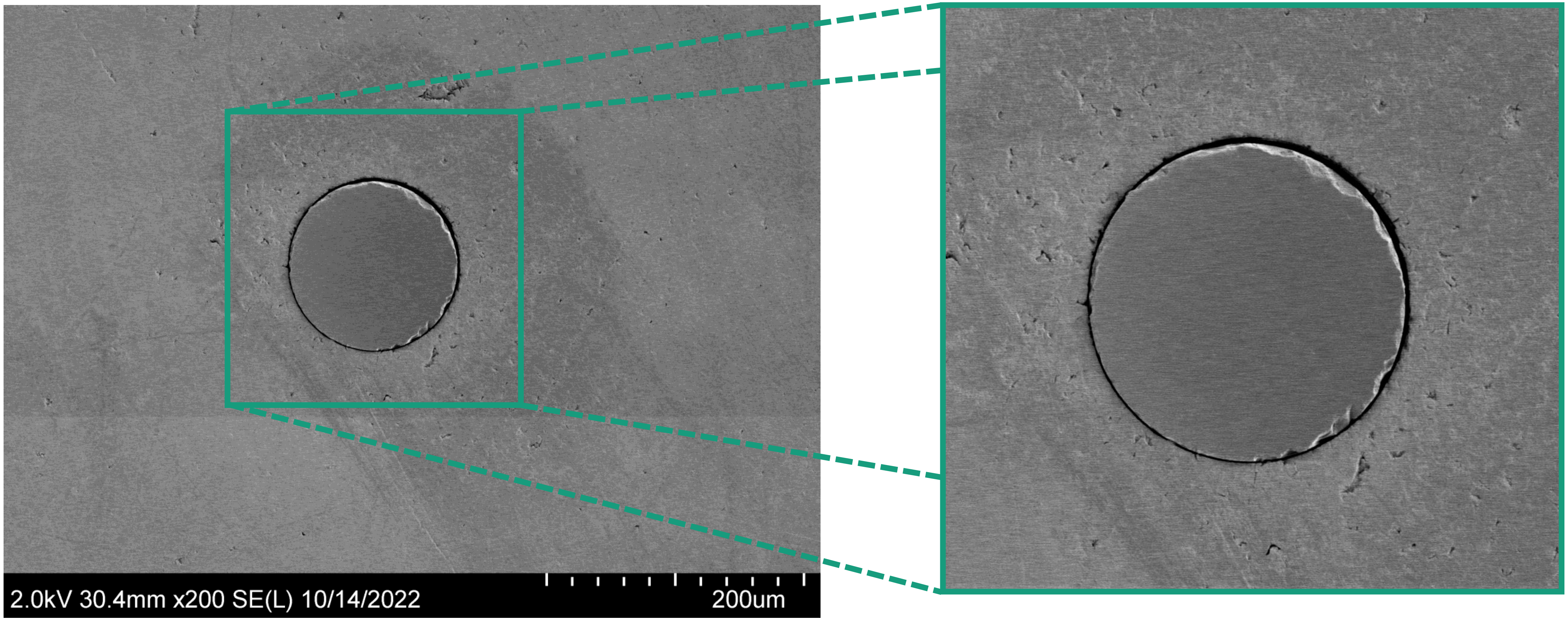
3 µm

1 µm

0.02 µm

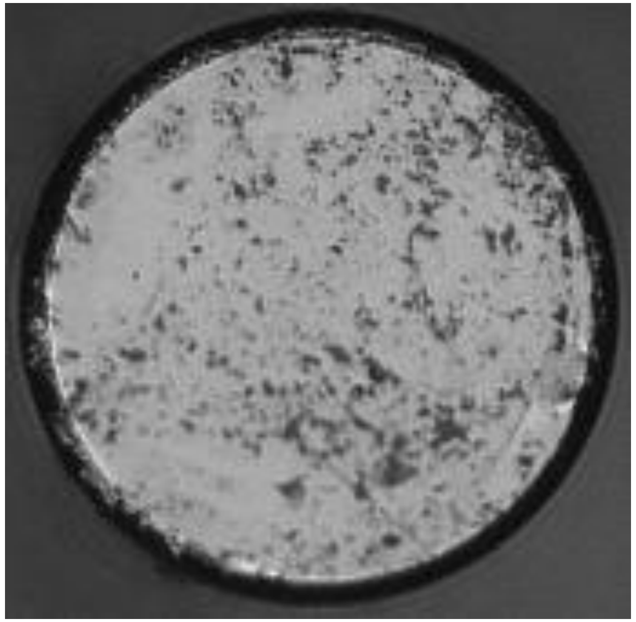
grit size of polishing paper

The SEM images reveal an excellent surface quality.



Extensive cleaning is essential.

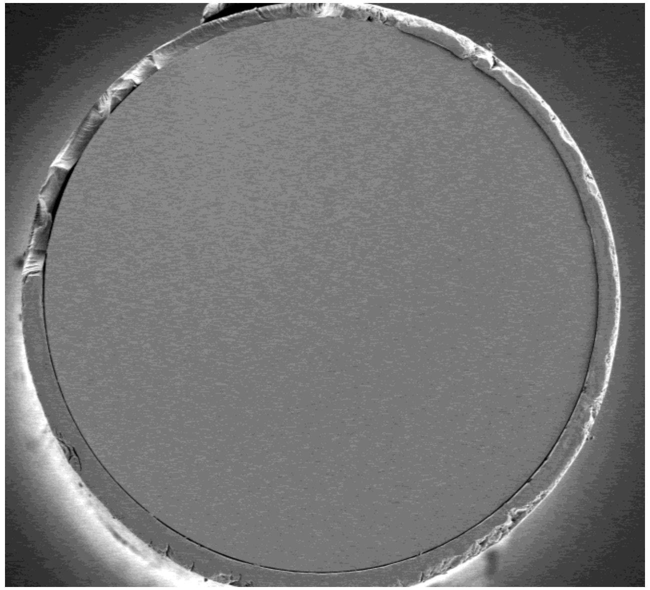
Surface quality of first fiber-tip STEs



microscopy image

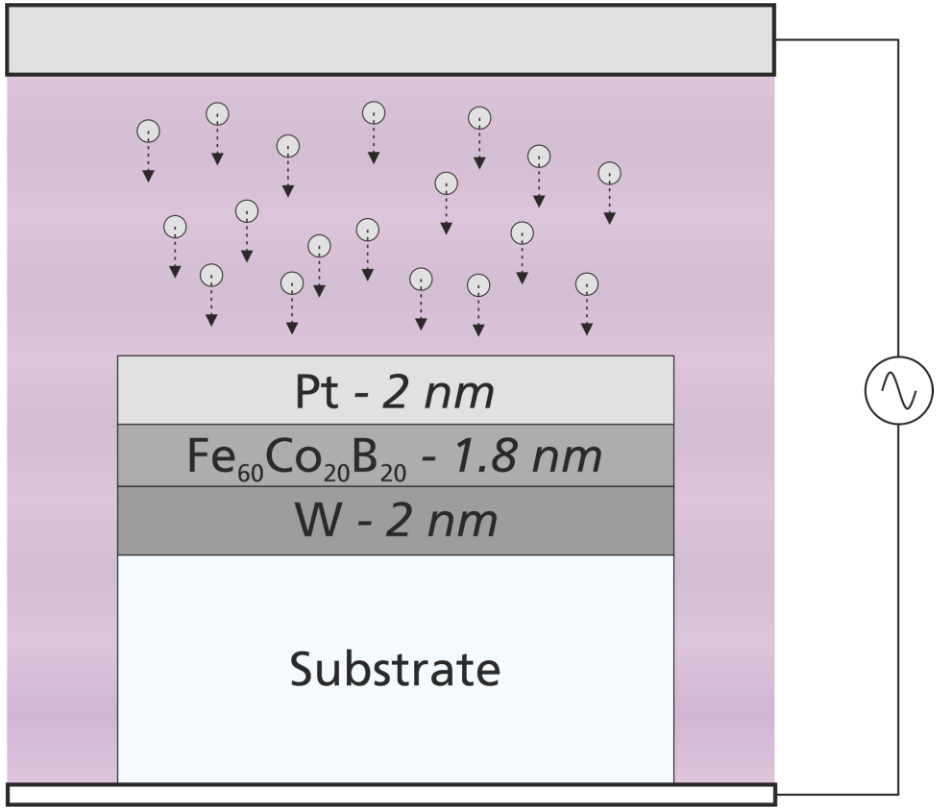
Extensive cleaning procedure and quality control

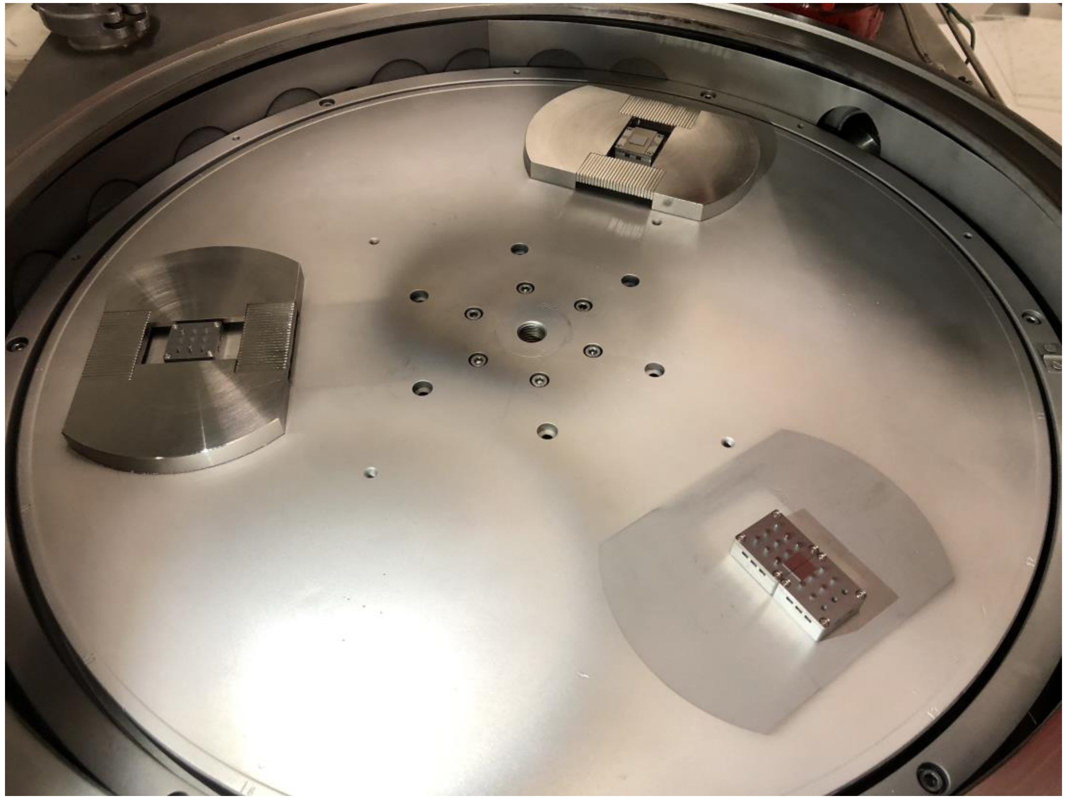
Surface quality of current fiber-tip STEs



SEM image

A tri-layer STE is sputtered onto the fiber tips.





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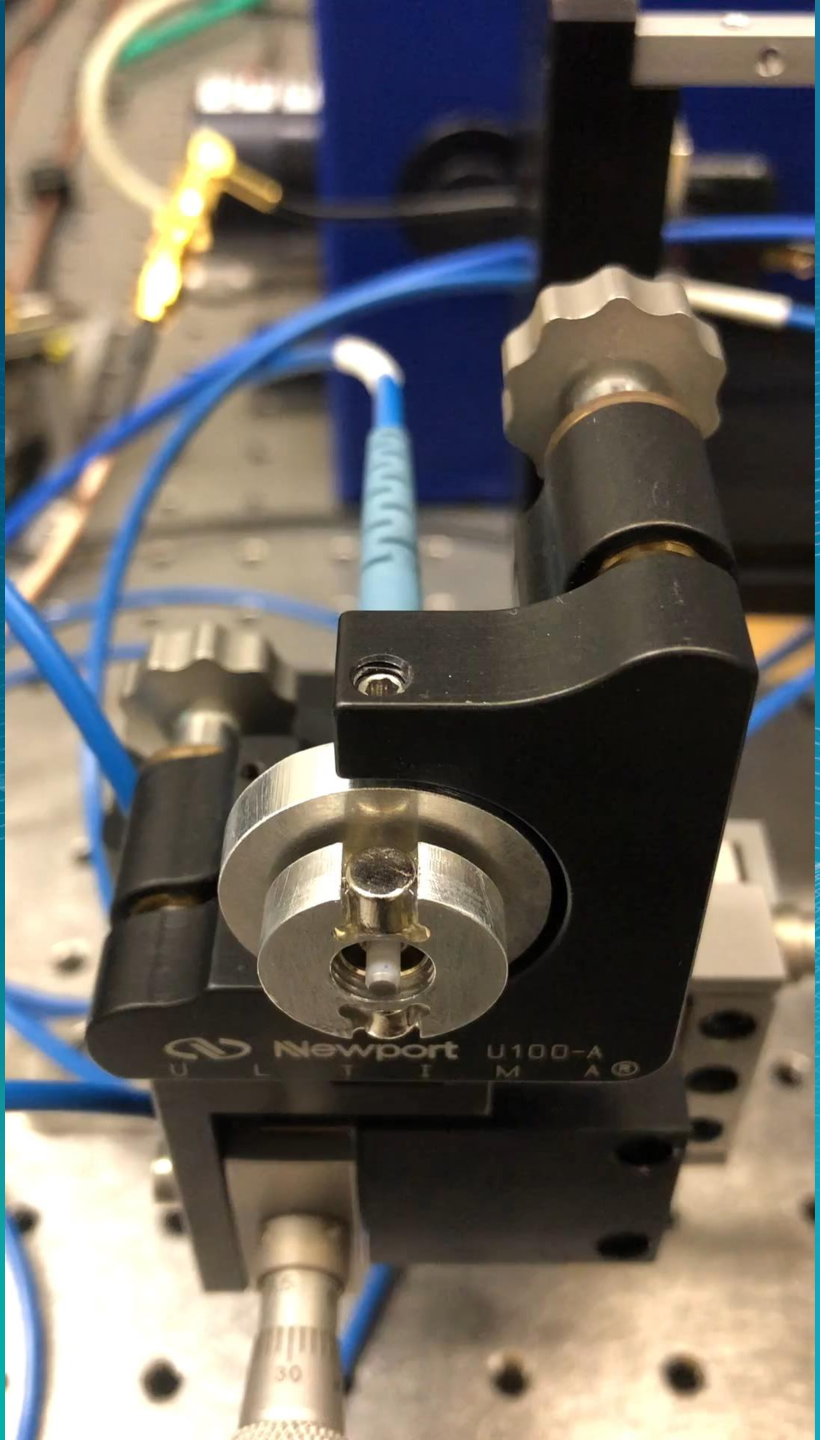
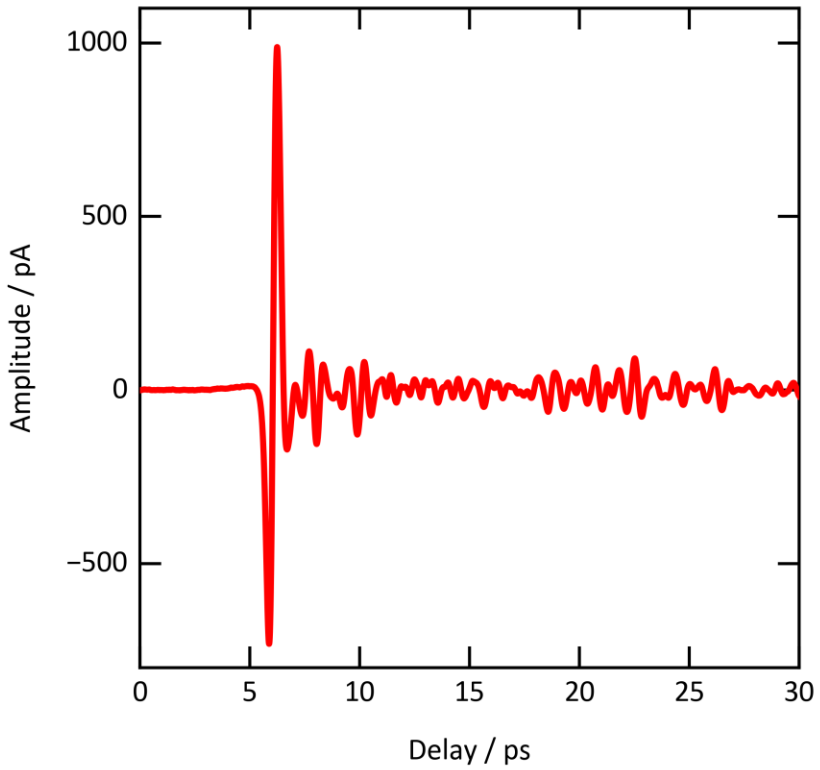
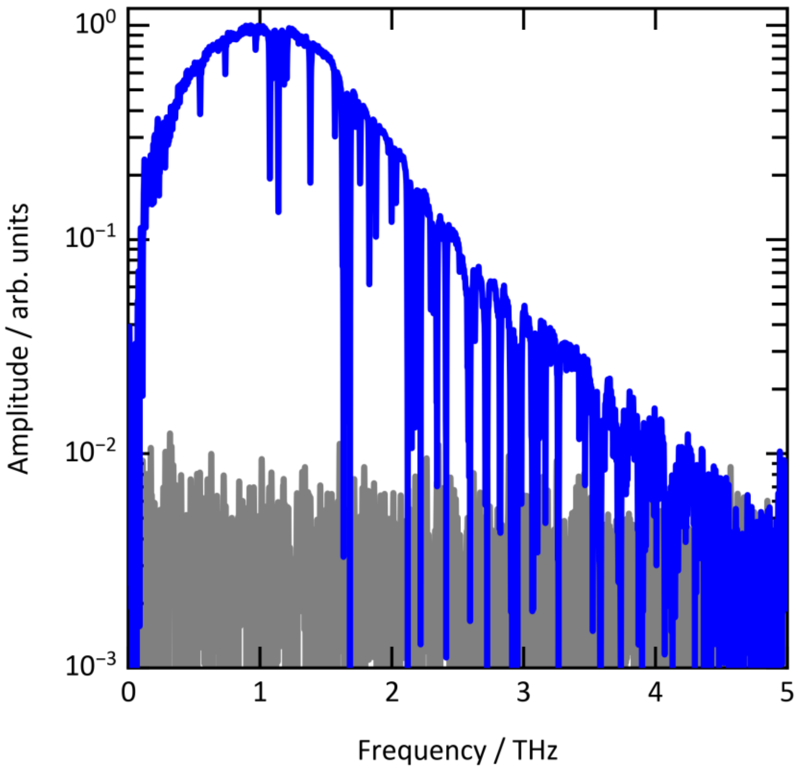


- fully fiber-coupled
- seamless integration into any existing laboratory setup
- exchangeable within a minute
- rotatable external magnet

The fiber-tip STEs exhibit the same performance as conventional free-space STEs.

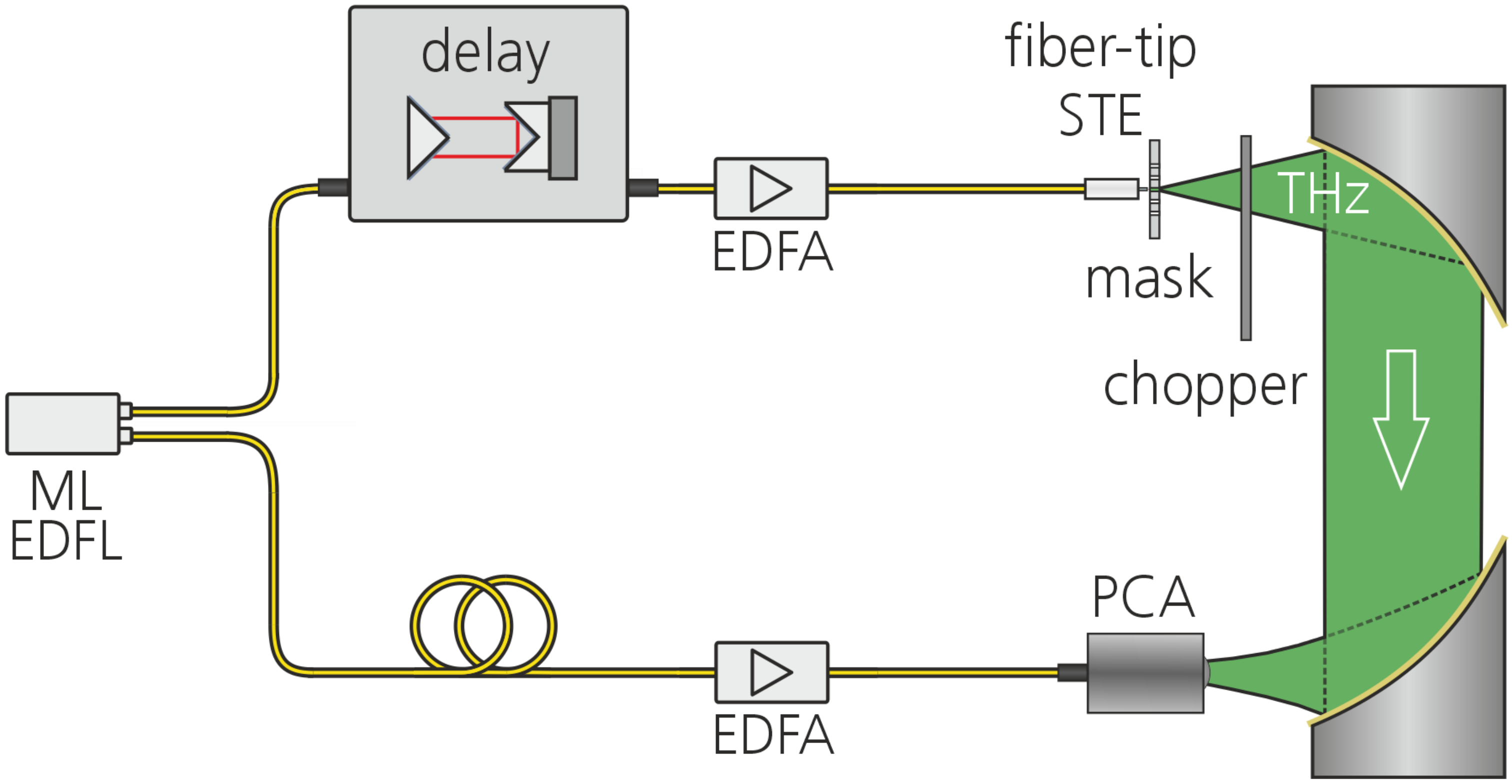




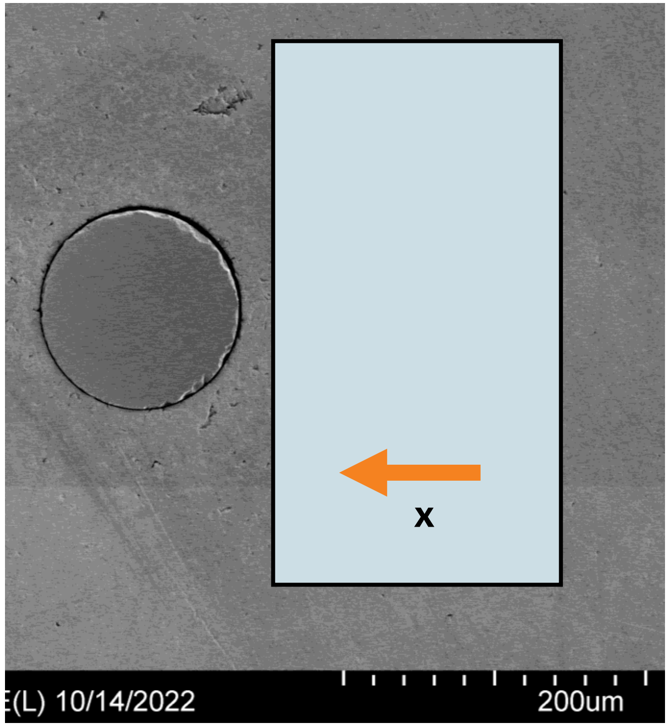
- pump fiber laser:
  150 mW, 100 MHz, 70 fs
  at 1550 nm
- dynamic range:
  ~ 42 dB

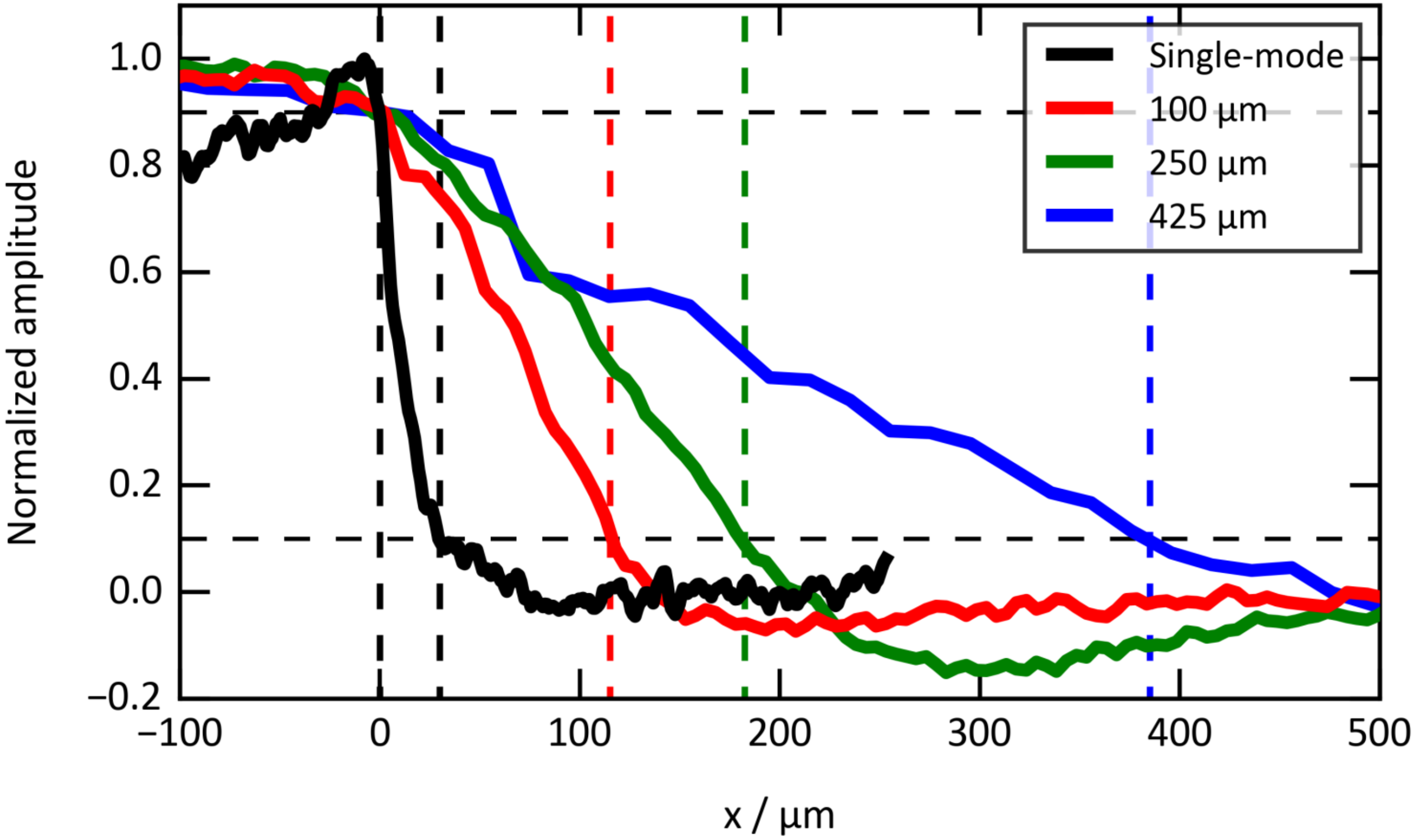
What are possible applications?

Single-mode fiber-tip STEs naturally lead to a simple terahertz near-field imaging system.

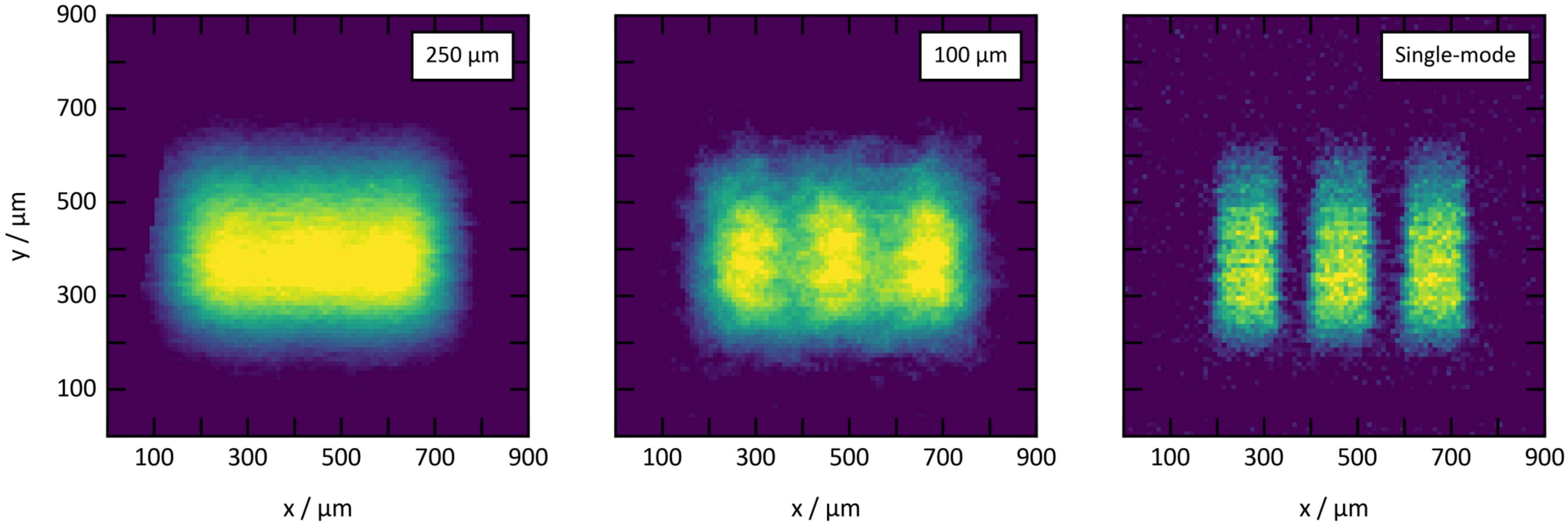


A 90%-10% knife-edge resolution of 30 µm is achieved using single-mode fiber-tip STEs.

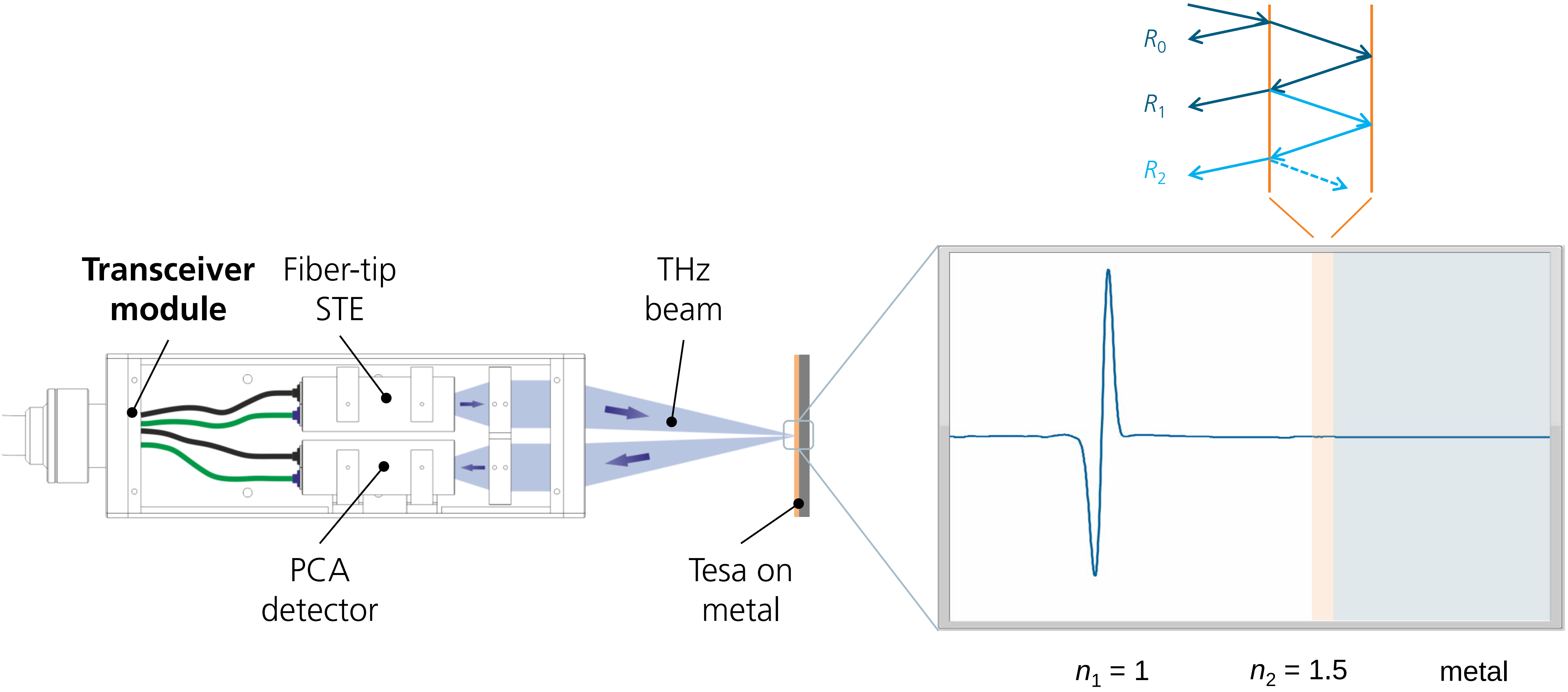




Two metal strips with a width of 77.5 µm and a spacing of 122.5 µm are clearly resolved with the single-mode fiber-tip STEs.

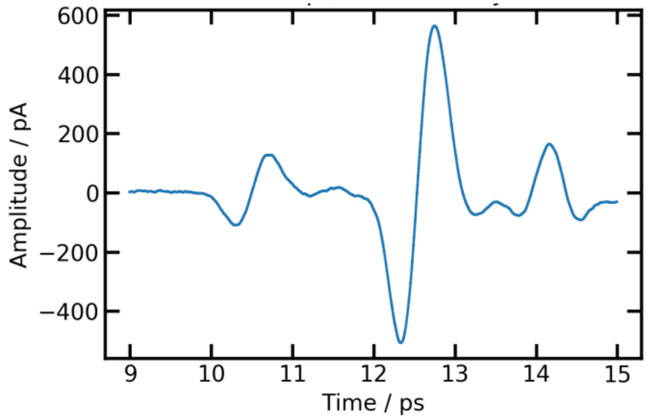


A proof-of-concept layer thickness determination has been shown.

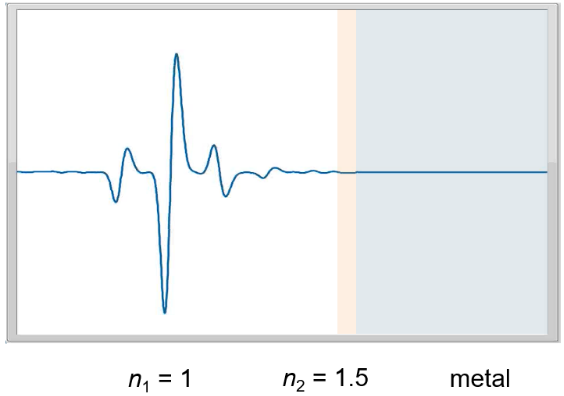


A proof-of-concept layer thickness determination has been shown.

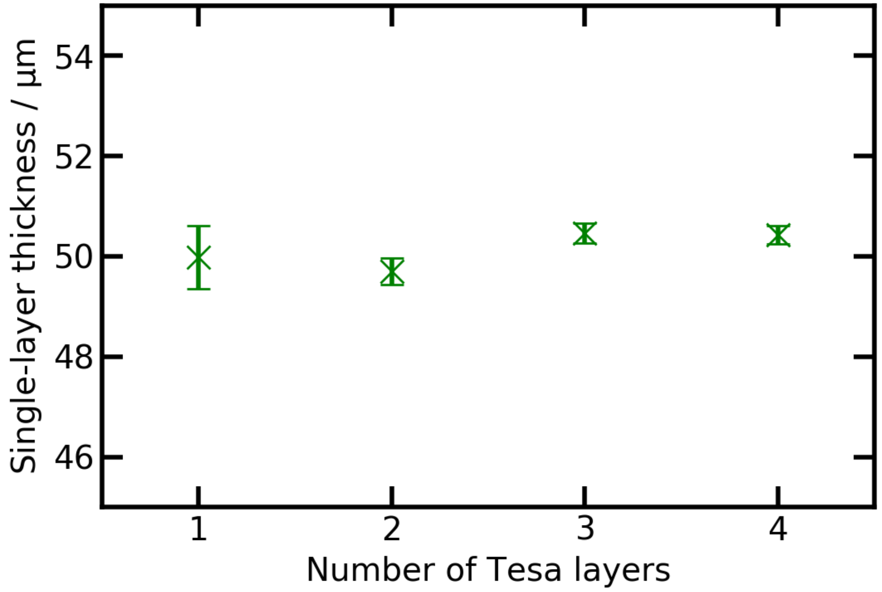
Experiment



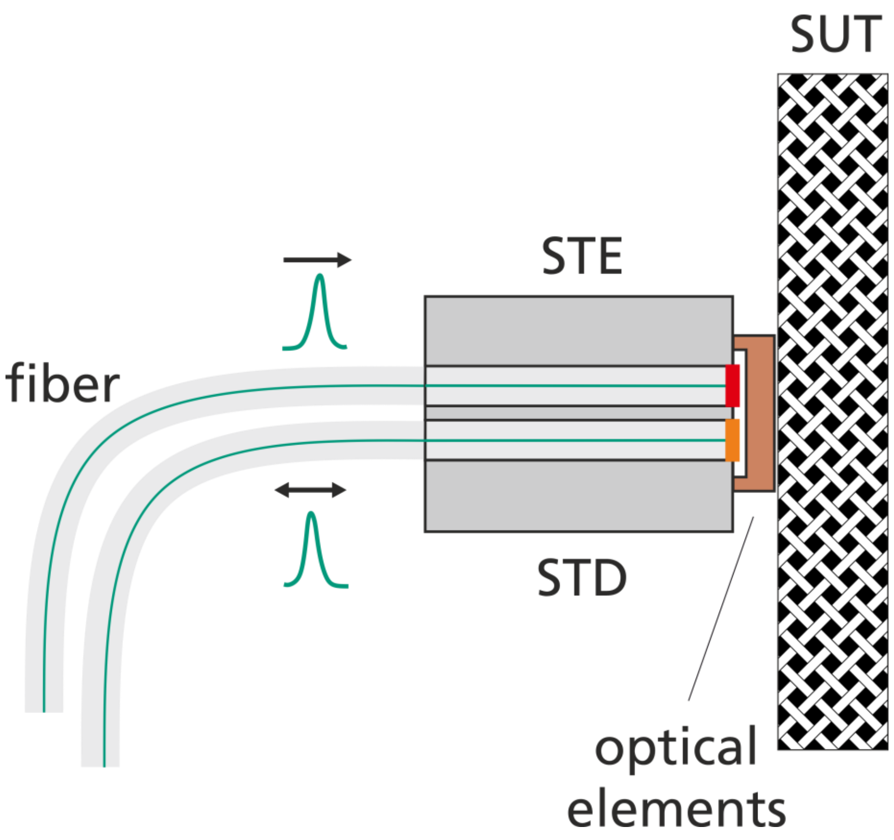
Simulation



Layer thickness determination

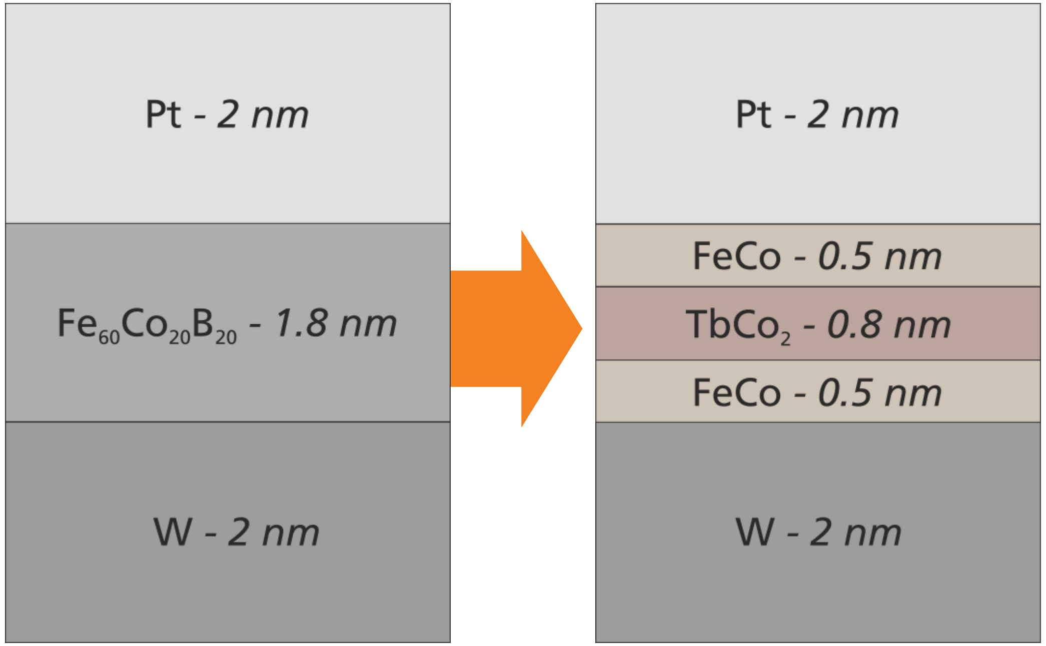


Fiber-tip-STE based endoscopic measurements could become a reality at one point in time.

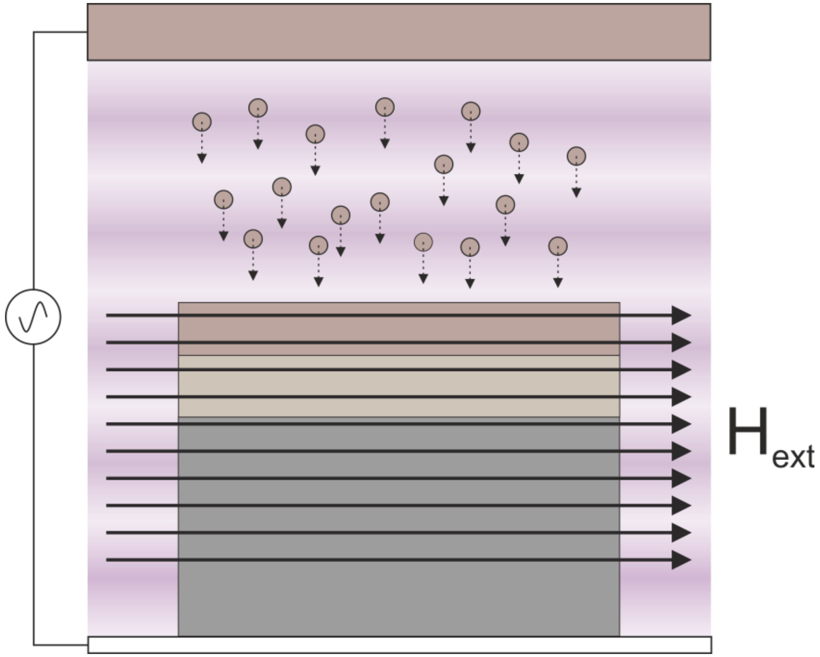


Magnetic-bias-free fiber-tip STEs are possible.

Change of material

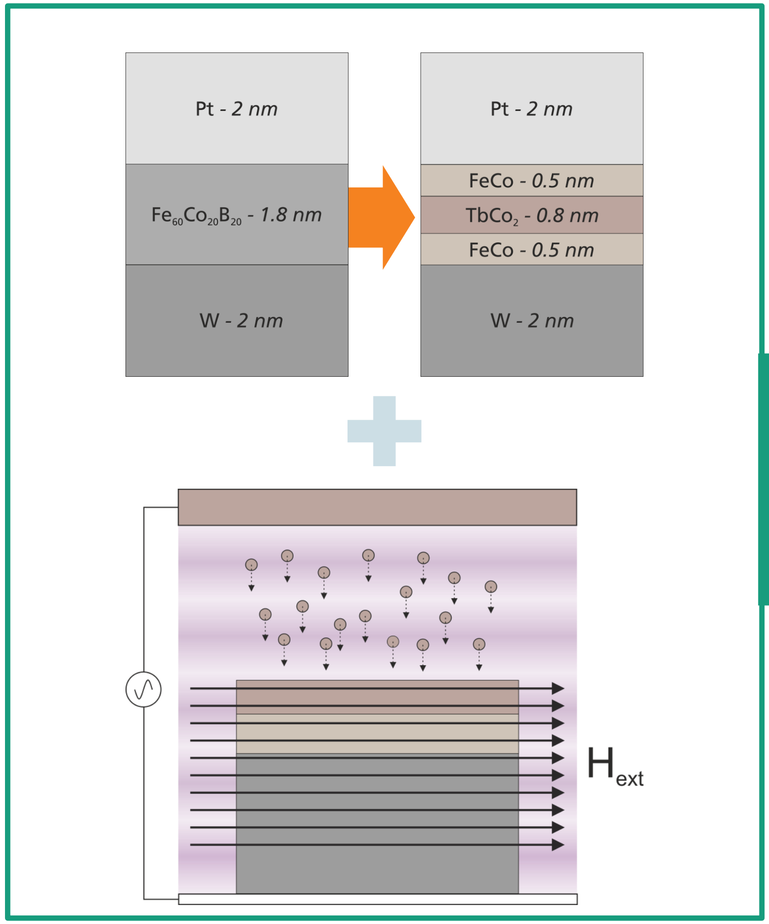


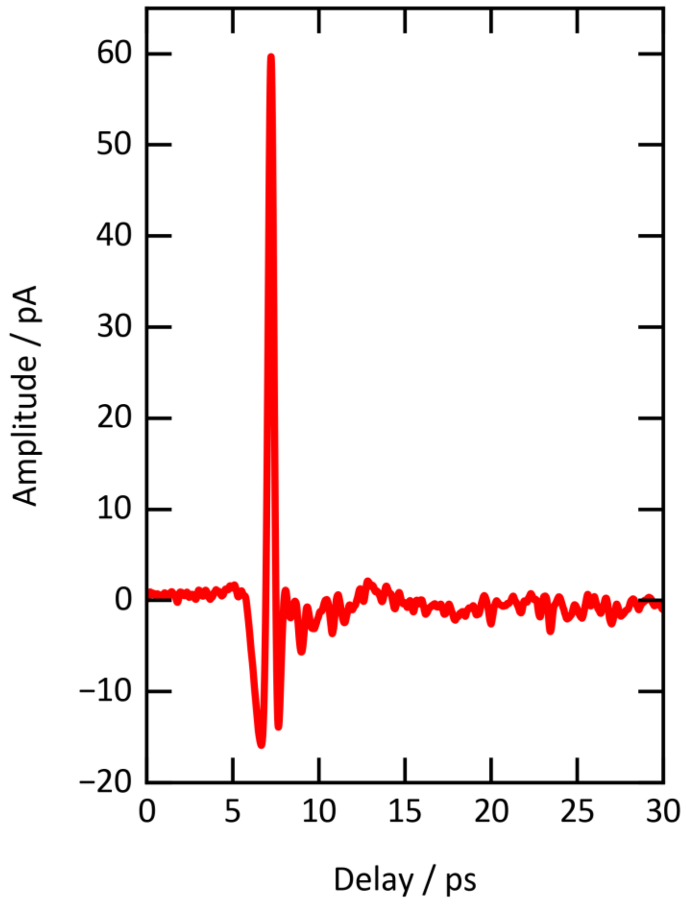
Inducing anisotropy by a strong external magnetic field



P. Koleják, et al.; *„360° Polarization Control of Terahertz Spintronic Emitters Using Uniaxial FeCo/TbCo2/FeCo Trilayers“;* *ACS Photonics* (2022)

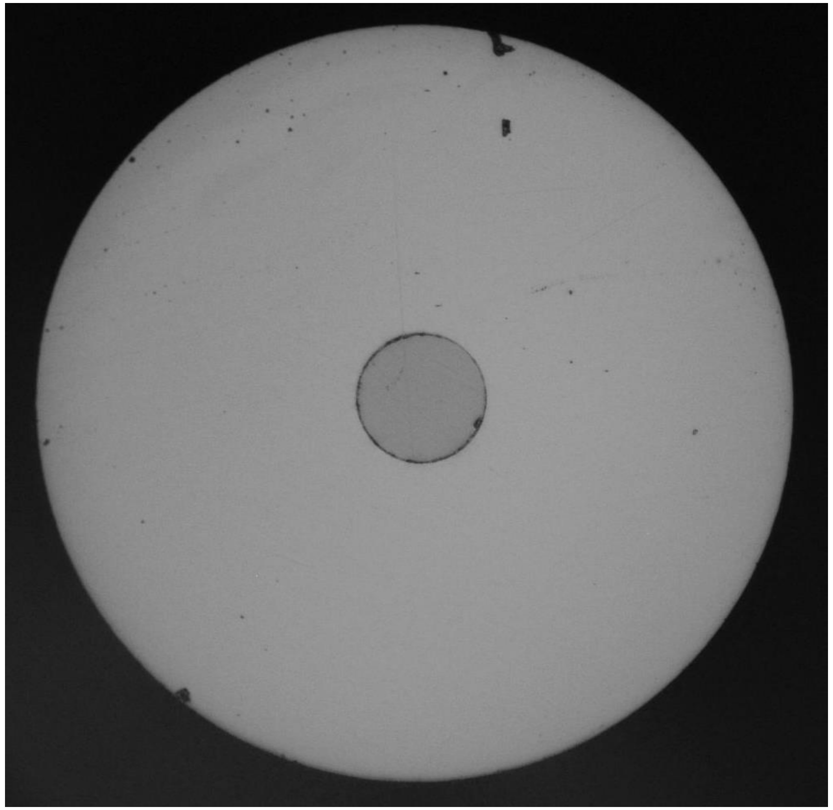
Magnetic-bias-free fiber-tip STEs are possible.



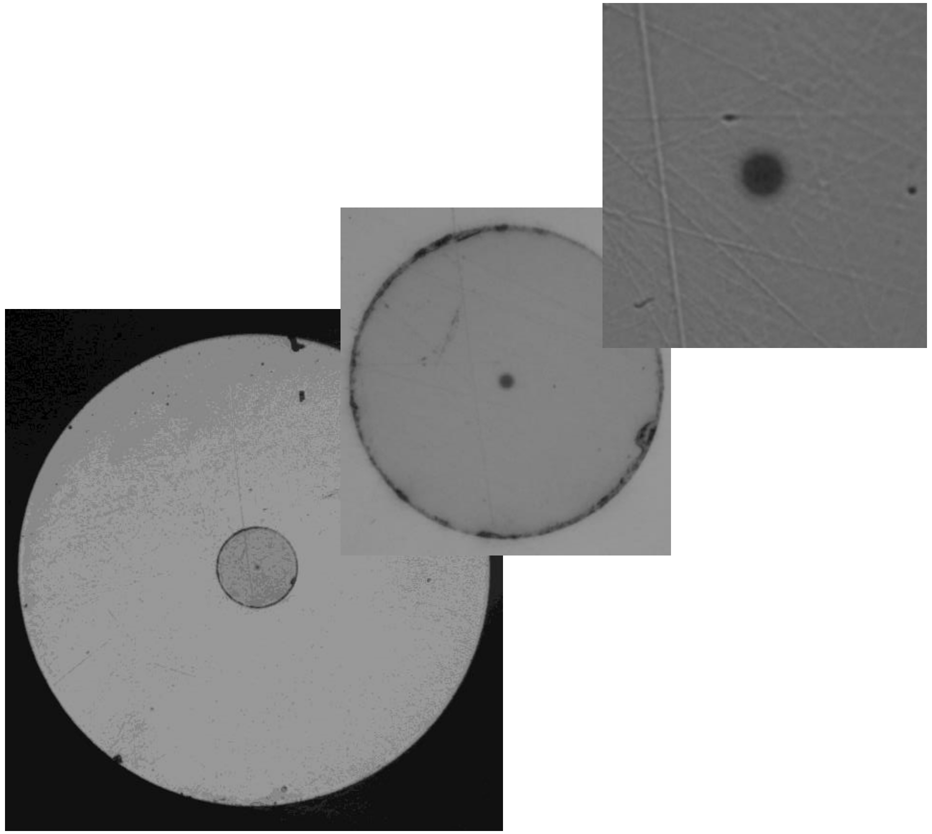


Optical damage threshold is a limiting factor.

before experiment



after experiment



This type of optical damage has already been mentioned in several publications.

U. Nandi, et al.
Appl. Phys. Lett. (2019)

Antenna-coupled spintronic terahertz emitters driven by a 1550 nm femtosecond laser oscillator

Cite as: Appl. Phys. Lett. **115**, 022405 (2019); https://doi.org/10.1063/1.5089421
Submitted: 18 January 2019 . Accepted: 15 June 2019 . Published Online: 09 July 2019

U. Nandi, M. S. Abdelaziz, S. Jaiswal, G. Jakob, O. Gueckstock, S. M. Rouzegar, T. S. Seifert, M. Kläui, T. Kampfrath, and S. Preu

free-space port. By increasing the laser power, the THz amplitude initially increased monotonically and eventually saturated at about 100 mW (Fig. 3). Upon further increase in the laser power, an irreversible drop of the THz amplitude was observed (Fig. 3). Microscopy inspection revealed a slight change in color (although the metal film was still intact), indicating damage to the structure. This effect may result from thermally driven diffusion of atoms between the metallic layers. We note that the SiO_x layer currently impedes heat transfer to the thermally well conducting Si substrate, which can be mitigated by omitting this layer or just reducing its thickness. We emphasize, how-

T. Vogel, et al.
Opt. Express (2022)

Average power scaling of THz spintronic emitters efficiently cooled in reflection geometry

TIM VOGEL,[1,*] ALAN OMAR,[1] SAMIRA MANSOURZADEH,[1] FRANK WULF,[1] NATALIA MARTÍN SABANÉS,[2,3] MELANIE MÜLLER,[4] TOM S. SEIFERT,[2] ALEXANDER WEIGEL,[5,6,7] GERHARD JAKOB,[8] MATHIAS KLÄUI,[8] IOACHIM PUPEZA,[5,6] TOBIAS KAMPFRATH,[2,4] AND CLARA J. SARACENO[1]

with average power indicating other limiting mechanisms are in place, too. Beyond that point, the saturation behavior also depends on the repetition rate: in the case of highest repetition rate (400 kHz), a strong drop in the obtained power is visible, illustrating the onset of strong thermal effects which ultimately degrade the metallic structure [43]. For decreasing repetition rates, this

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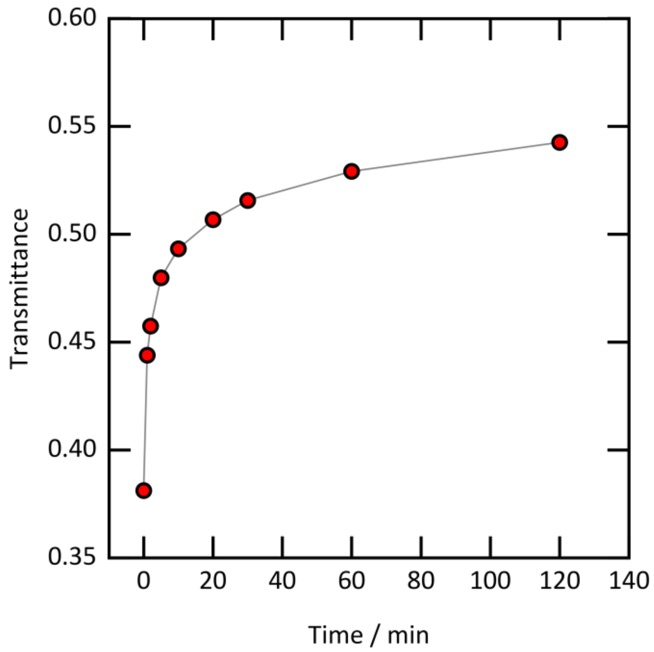
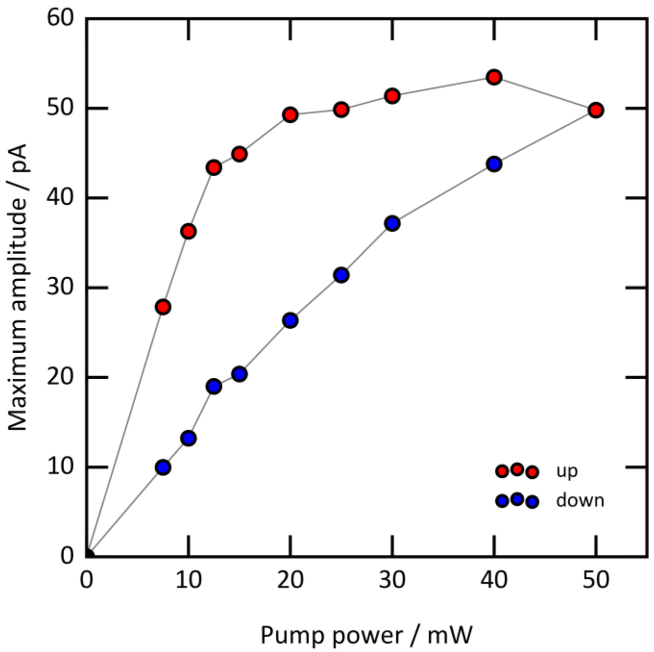
Infrared-transmittance and THz-amplitude measurements indicate a heat-based problem.

IR transmittance



THz amplitude



single-mode fiber-tip STE

+

pump laser

- central wavelength 1550 nm
- 100 MHz
- 70 fs FWHM

optical power density threshold

< 2 kW/cm²

publication in preparation

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Outlook: Physics is the limit!

Today → → Future → ?

simple prototyping-tool
to
easily manufacture
a variety of different samples
with an equal and clearly
defined pump mode-field

fully fiber-coupled
STE systems

endoscopic
measurements

integrated terahertz
photonics

„STE-on-a-chip“

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Fraunhofer
ITWM

"Fiber-tip spintronic terahertz emitters"
F. Paries, et al. (2023)

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