Synchrotron and Free electron laser Radiation: generation and application (SFR-2020)

Modeling of terahertz surface plasmon Fourier-spectrometer

Nikitin A.K.[1)], Khitrov O.V.[1)], Gerasimov V.V.[2)]

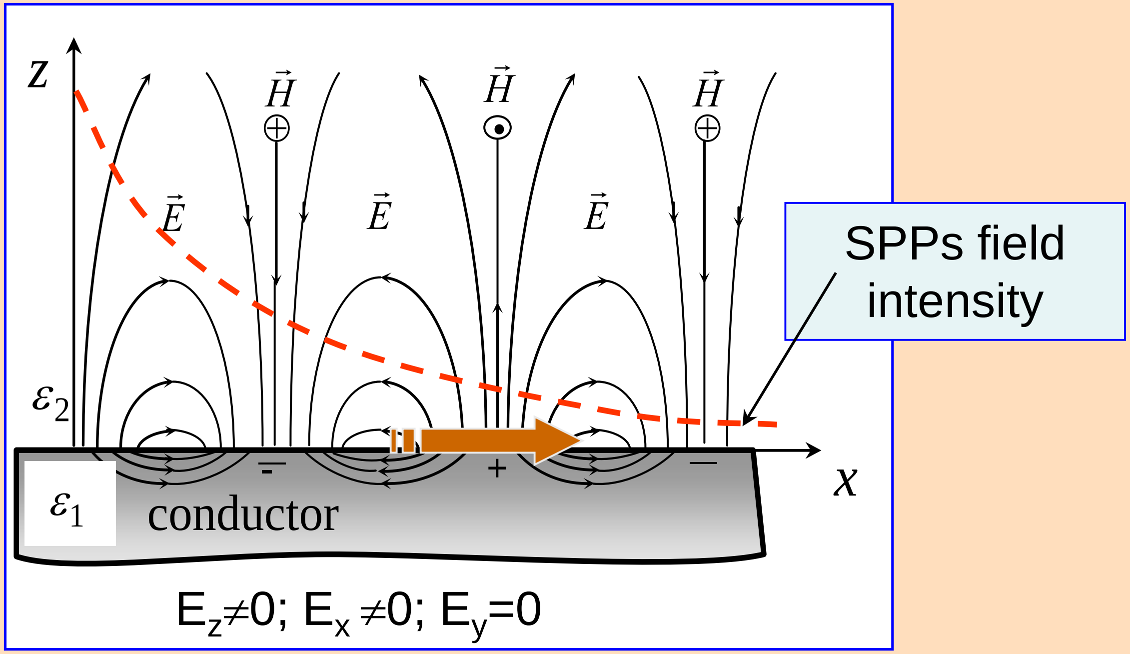
[1] Scientific and Technological Center for Unique Instrumentation of RAS, Moscow

[2] Budker Institute of Nuclear Physics SB RAS, Novosibirsk, Russia

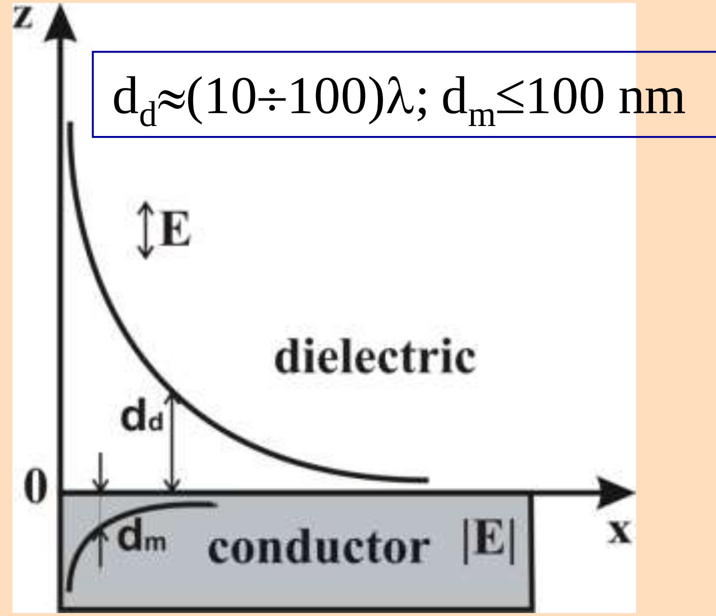
Novosibirsk - 2020

Surface plasmons (SPs) running along “Metal (ε_1) – Dielectric (ε_2)” interface

Snapshot of the SPPs field



SPPs field is concentrated in the vicinity of the metal surface



SPPs can exist only under the condition: $\mathrm{Re}(\varepsilon_1) < -\varepsilon_2$

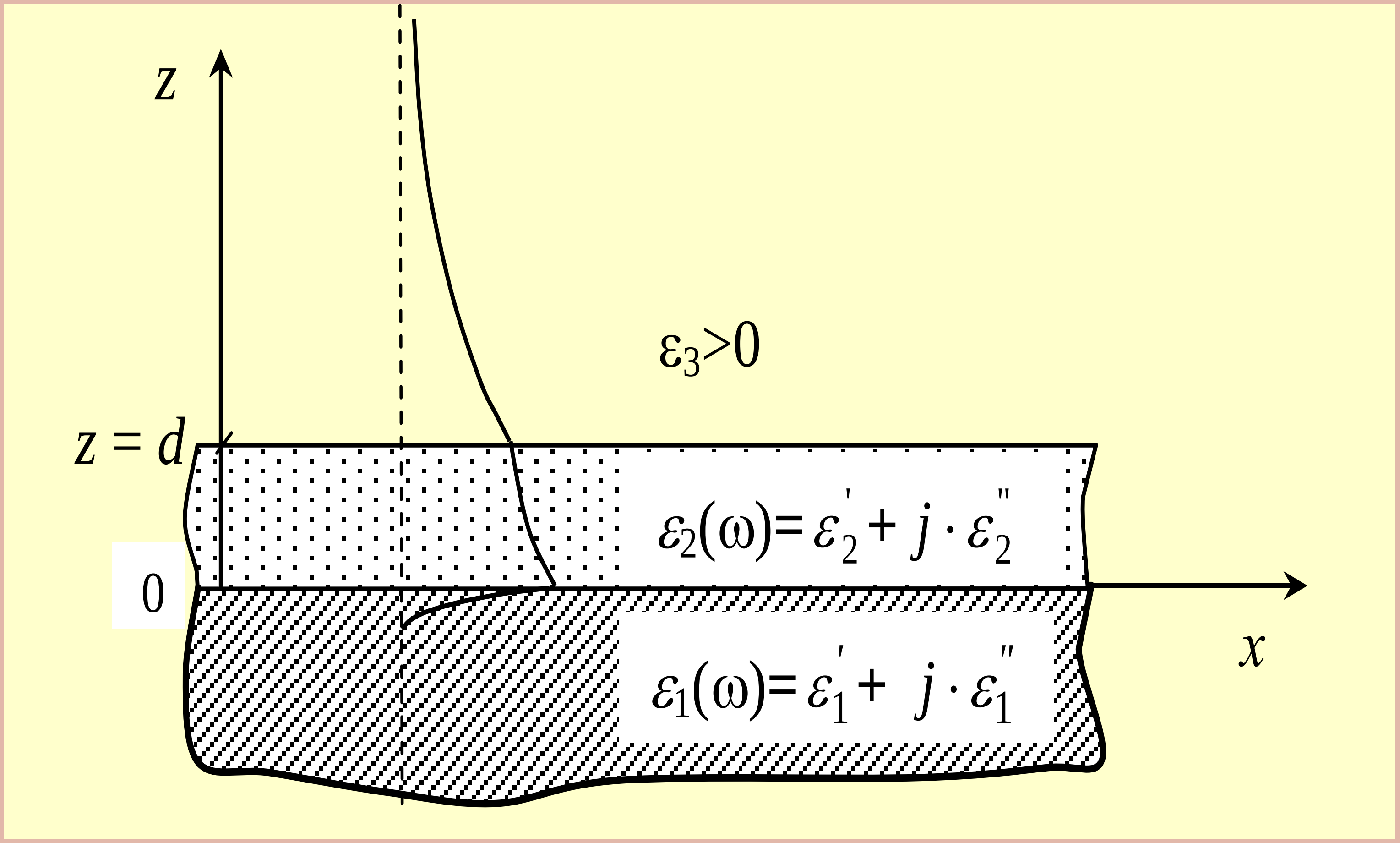
SPPs complex refractive index

$$\kappa = \kappa' + i \cdot \kappa'' = \sqrt{\frac{\varepsilon_1 \cdot \varepsilon_2}{\varepsilon_1 + \varepsilon_2}}$$

SPPs propagation length

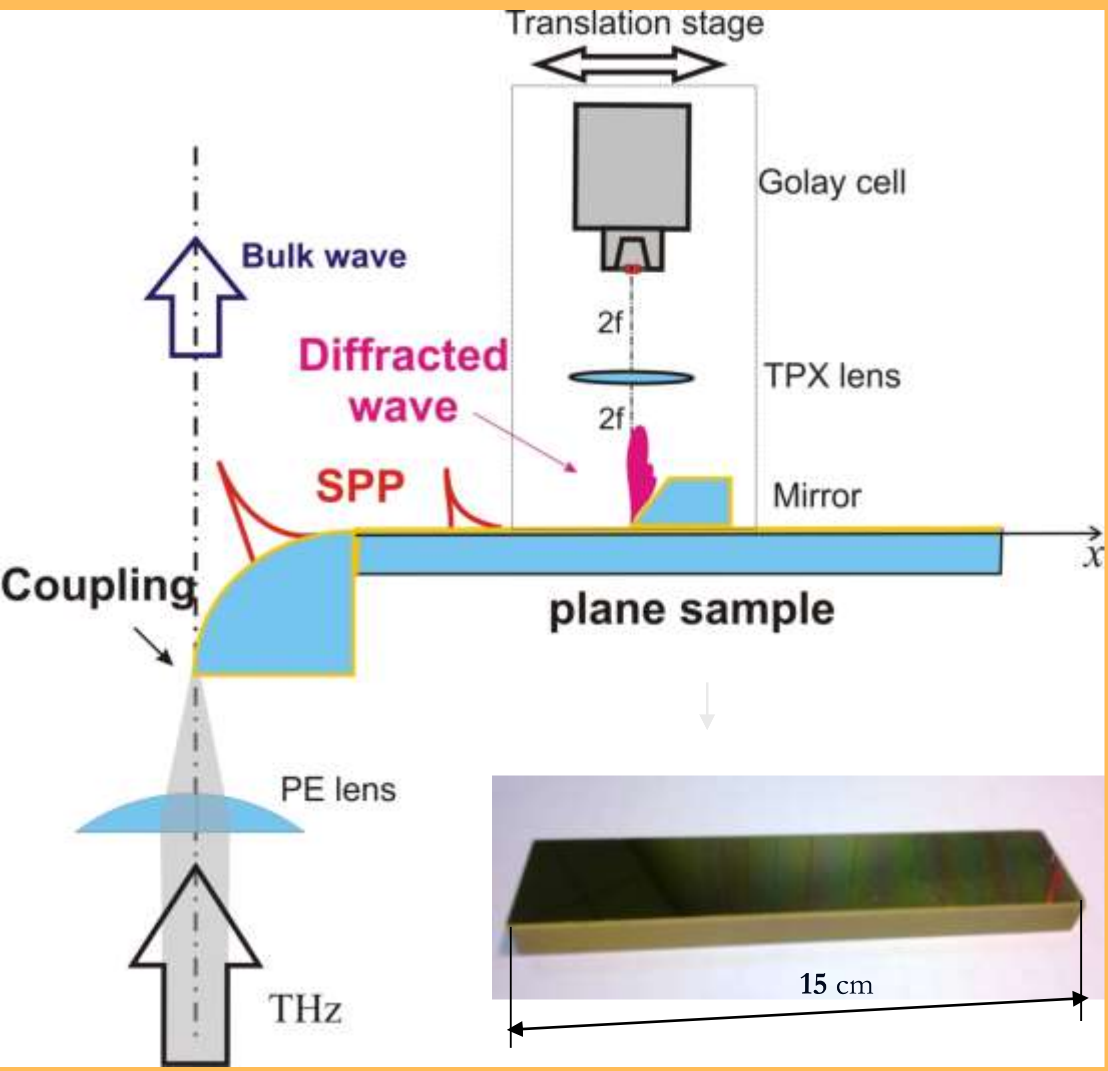
$$L = \lambda/(4\pi \cdot \kappa''), \qquad \vartheta_{ph} = C/\kappa'$$

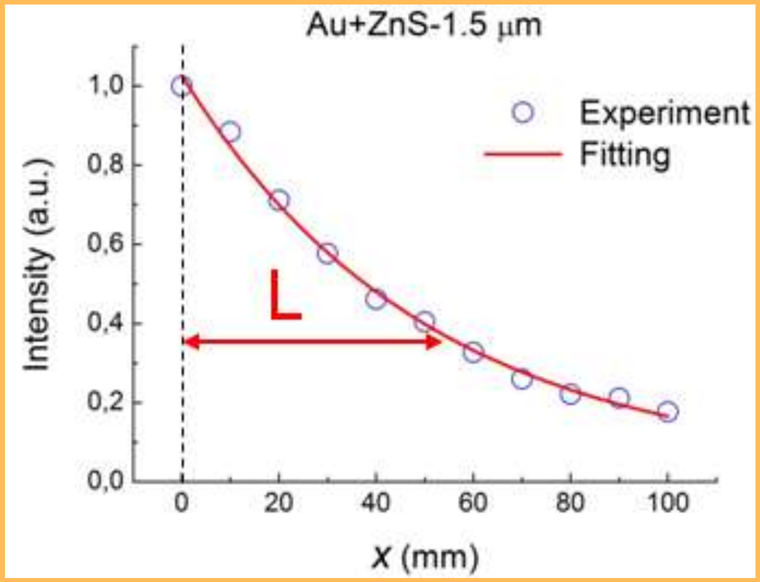
Distribution of SP field in 3-layer structure

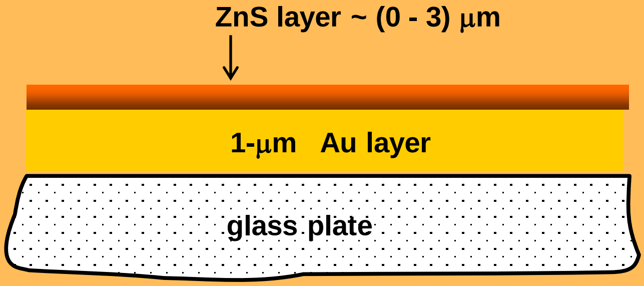


Measurement of THz SPs (λ=130 μm) propagation length on flat metal (Au) samples

Gerasimov V.V., Knyazev B.A., Kotelnikov I.A., Nikitin A.K., Kulipanov G.N., Zhizhin G.N.
Surface plasmons launched by a terahertz free electron laser // ***JOSA*** (***B***), **2013**, v.30 (8), p.2182-2190

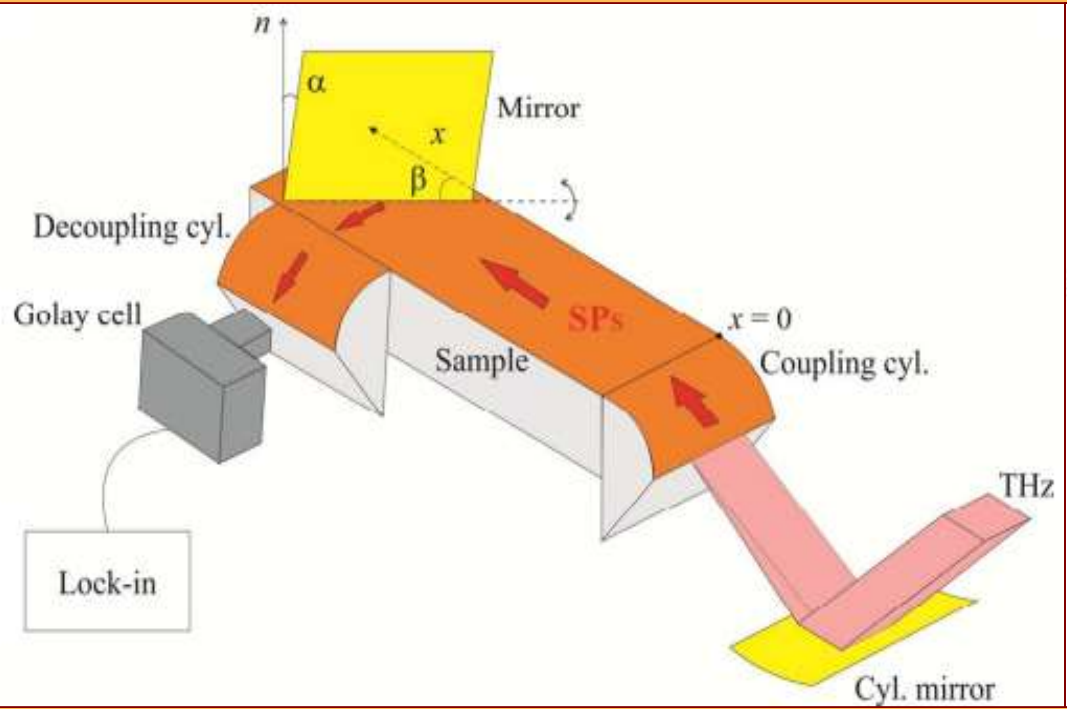


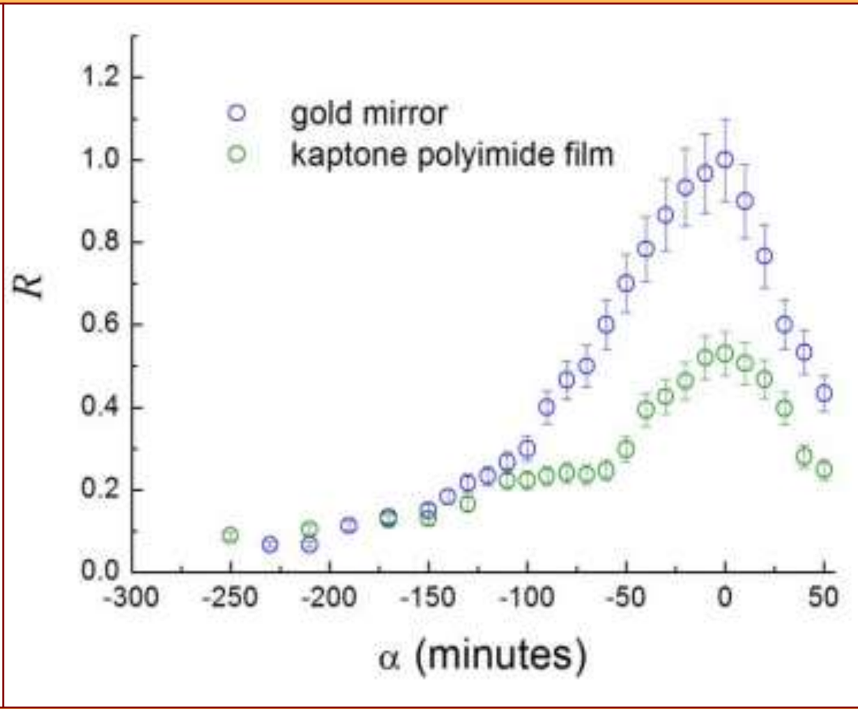




Reflection and slitting of THz SPs by plane mirrors and beam-splitters

V.V. Gerasimov, B.A. Knyazev, A.K. Nikitin // ***Quantum Electronics***, **2017**, v.47(1), p.65–70





Summary:

1) THz SPs can be reflected by a flat mirror if the penetration depth of their field into air exceeds ≈ 3 λ;

2) The intensity of the reflected THz SPPs beam can be adjusted by the angle of deflection of the mirror from the normal to the sample surface;

3) THz SPPs beam can be divided by means of a beam-splitting plate.

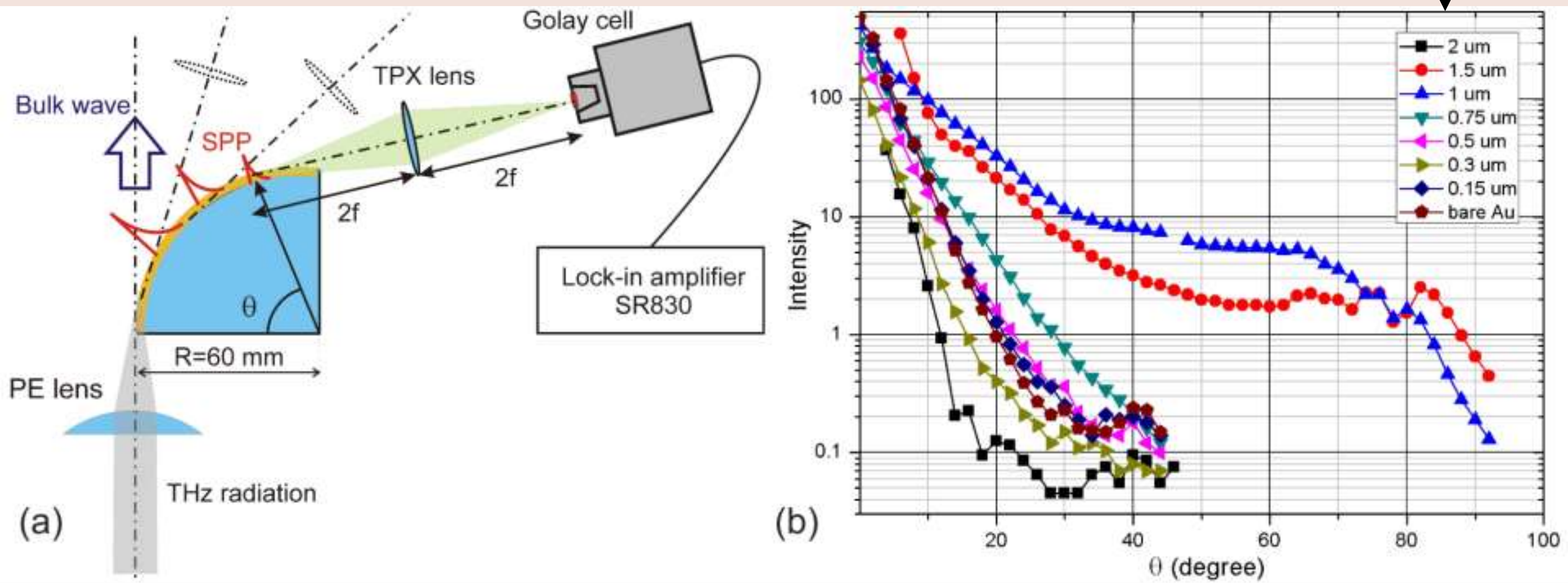
Propagation of THz surface plasmons around convex metal–dielectric interfaces

Knyazev B.A., Gerasimov V.V., Nikitin A.K. // **JOSA (B)**, **2019**, v.36(6), p.1684-1689

Structure: “Au – ZnS layer (*d*) – Air”

λ = 130 μm

d

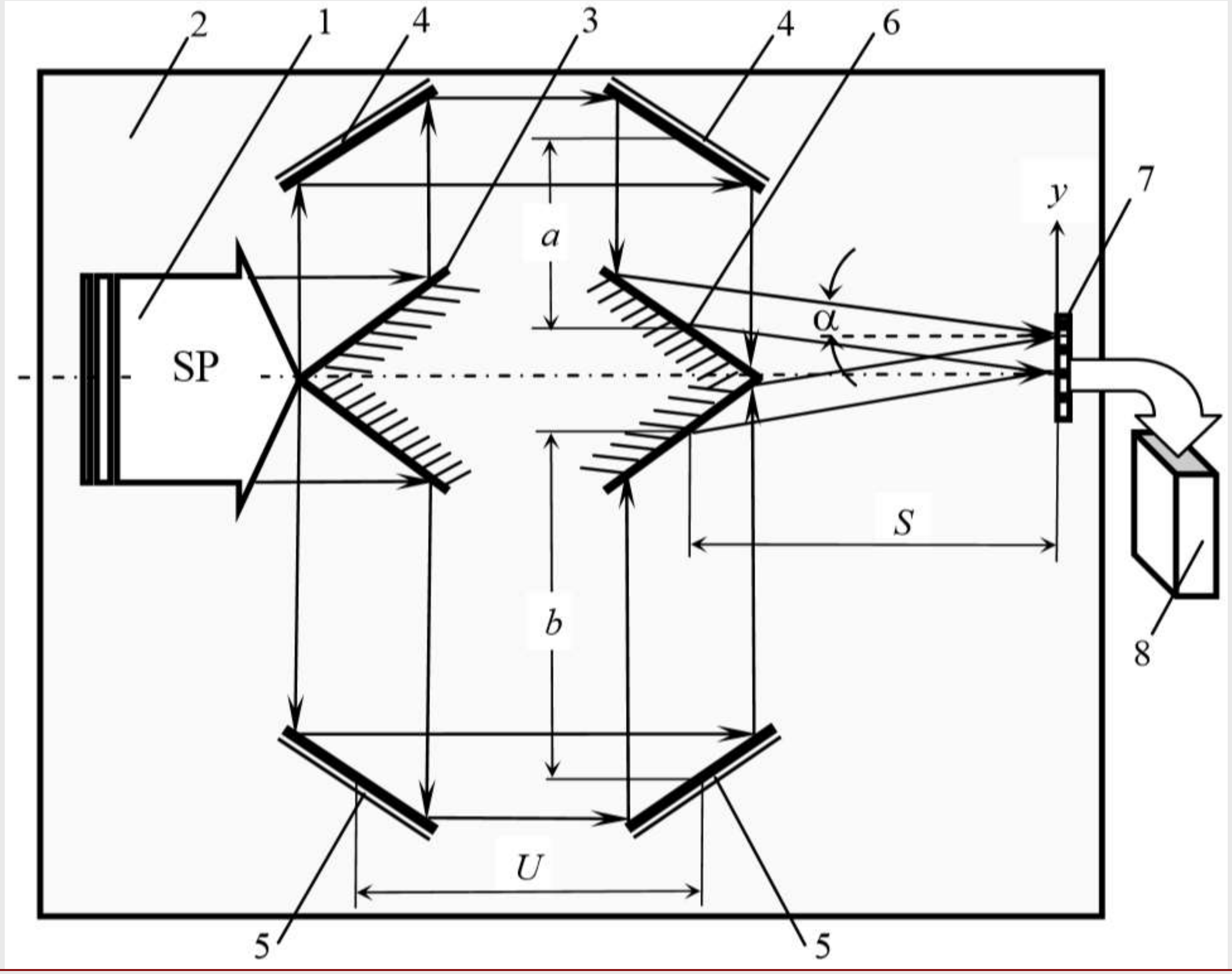


(a) Experimental schematic.

(b) Results of experiments.

Static THz SP interferometer with a corner-mirror beam splitter

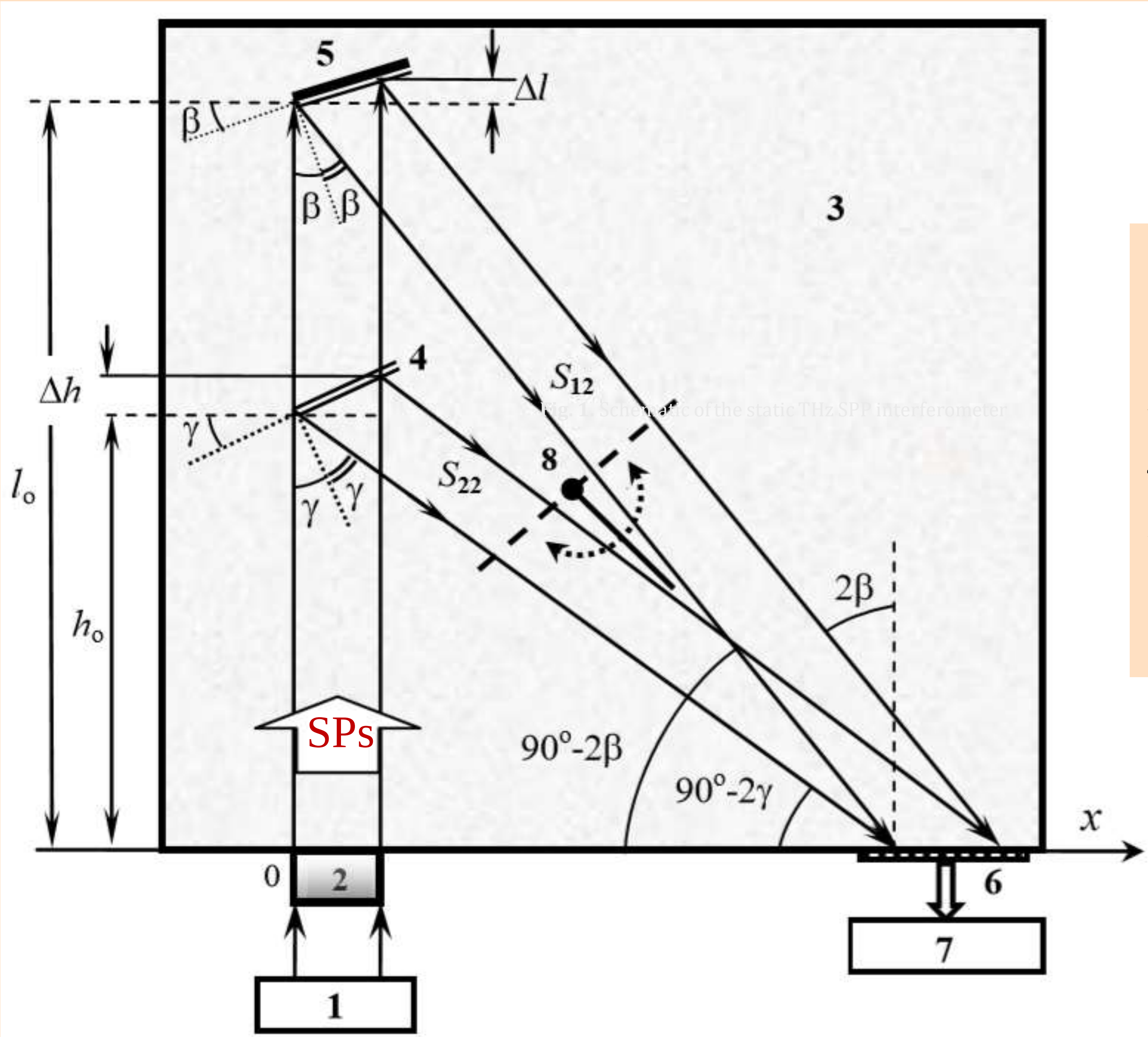
Nikitin A.K., Khitrov O.V., Kyrianov A.P., Knyazev B.A. //
Proc. SPIE, **2010**, v.7376, Art.7376 0U



1 – initial SP beam; 3 and 6 – corner mirrors; 7 - array of photo detectors; 8 – computer.

THz SP static interferometer with a flat-plate beam splitter

Nikitin A.K., Khitrov O.V., Gerasimov V.V. // **J. Physics: Conf. Ser**., **2019**, v.1421, 012013



1 – source of IR radiation;

2 – coupling element;

3 – flat-facet sample;

4 - beam-splitter;

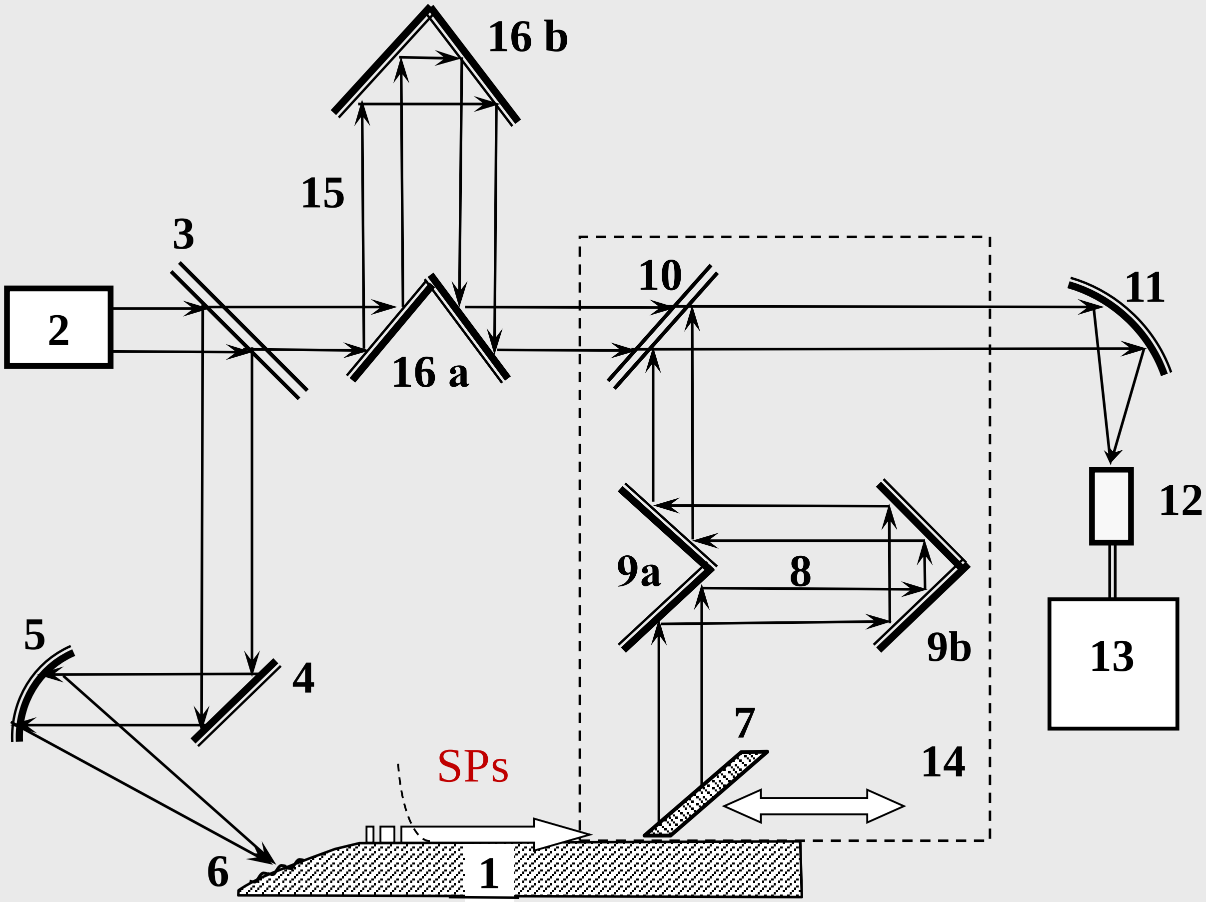
5 – mirror;

6 – photo detector array;

7 — computer;

Dynamic THz Fourier spectrometer with SPs in one of the shoulders

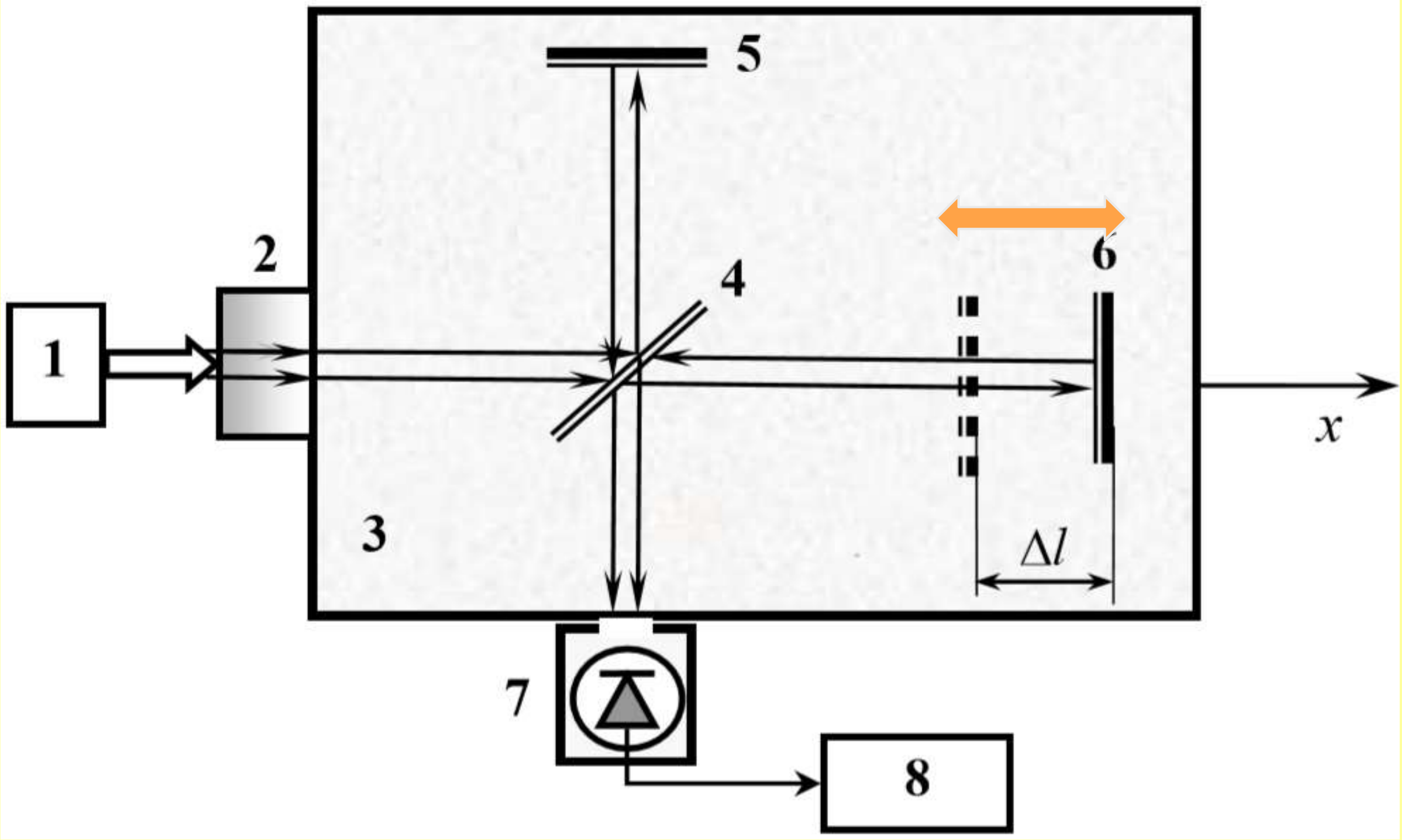
Kiryanov A.P., Nikitin A.K., Khitrov O.V. // *Optics and Spectroscopy*, **2012**, v.112, No.4, p. 545–550



1 – sample; 2 – source of broad-band radiation; 3 - beam-splitter; 4, 5 – mirrors; 6 - coupling element; 7 – movable mirror, transforming SPs in bulk radiation; 8 – delay line; 9a – fixed corner mirror; 9 b – movable corner mirror; 10 - beam-splitter; 12 – photo detector, 13 – computer; 14 – movable platform; 15 – auxiliary delay line.

Dynamic THz Fourier spectrometer based on Michelson interferometer with SPs in both shoulders

Nikitin A.K., Khitrov O.V. // **Patent of Russia** RU 2709600, 18.12.**2019**.



1 – broad-band THz radiation source; 2 – coupling element; 4 – flat plate beam splitter; 6 – discretely moving mirror; 7 - photo detector; 8 – computer.

Obtaining the absorption spectrum of THz SPs refractive index from two interferograms

The interference pattern :

$$I_{int}(\Delta x) = 2 \cdot \sum_{j=0}^{N} \left\{ \left(A_{0\nu}^{2} \right)_{j} \cdot D_{p} \cdot \exp\left(-2k_{ov\,j} \cdot \kappa''_{\nu\,j} \cdot (b + x + a) \right) \cdot \cos\left(2k_{ov\,j} \cdot \kappa'_{\nu\,j} \Delta x\right) \cdot \frac{\nu_{\max}}{N} \right\}$$

the complex radiation spectrum on the photodetector :

$$(\check{F})\left[\Delta I_{int}(\Delta x_{j}) = C_{\nu j} + i \cdot S_{\nu j}\right]$$

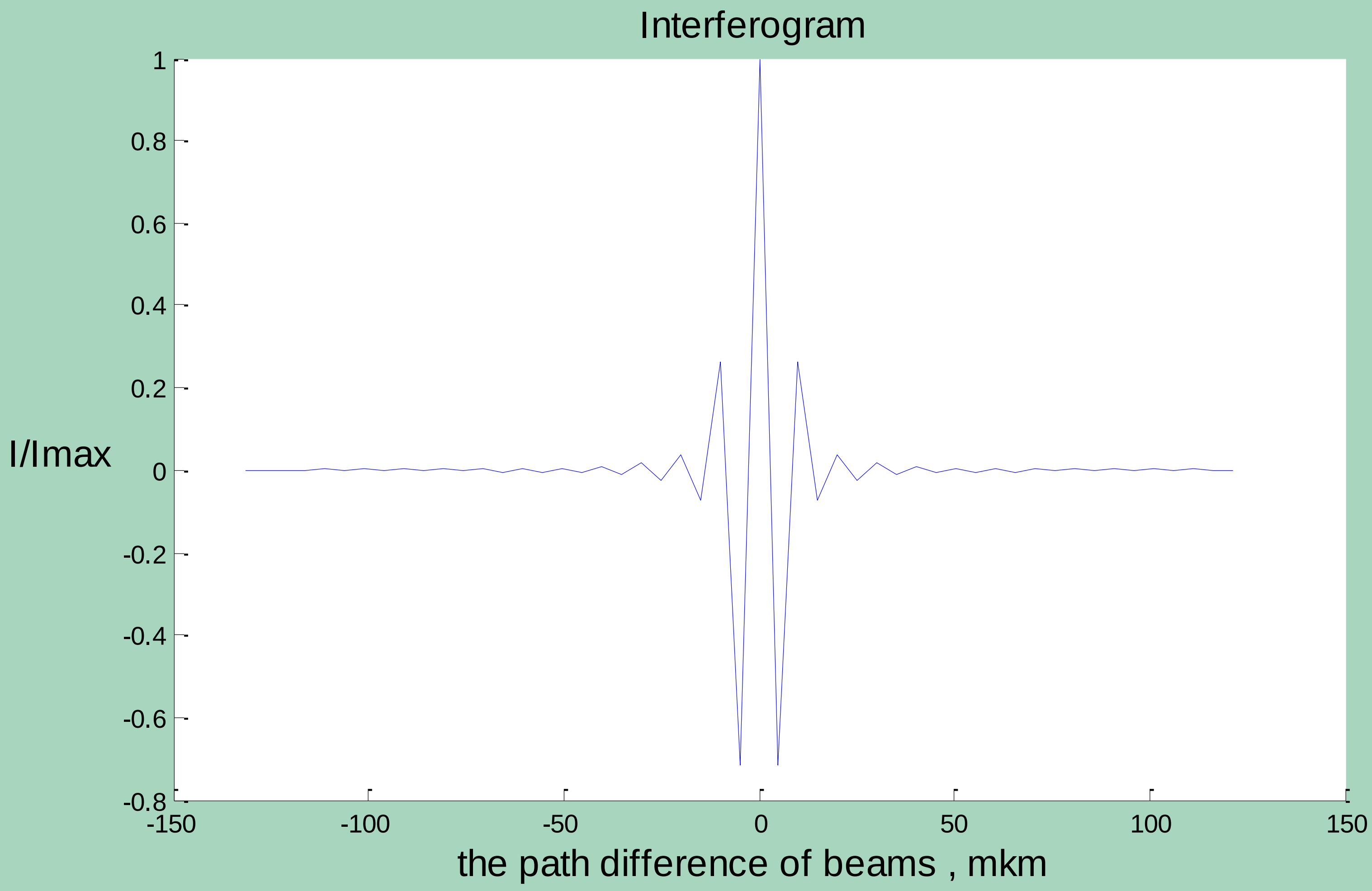
the amplitude spectrum of the radiation on the photodetector :

$$A_{\nu j} = \sqrt{C_{\nu j}^{2} + S_{\nu j}^{2}} = D_{p} \cdot \exp\left(-2k_{ov\,j} \cdot \kappa''_{\nu\,j} \cdot (b + x + a) \right),$$

Spectrum of the imaginary part of the SP refractive index:

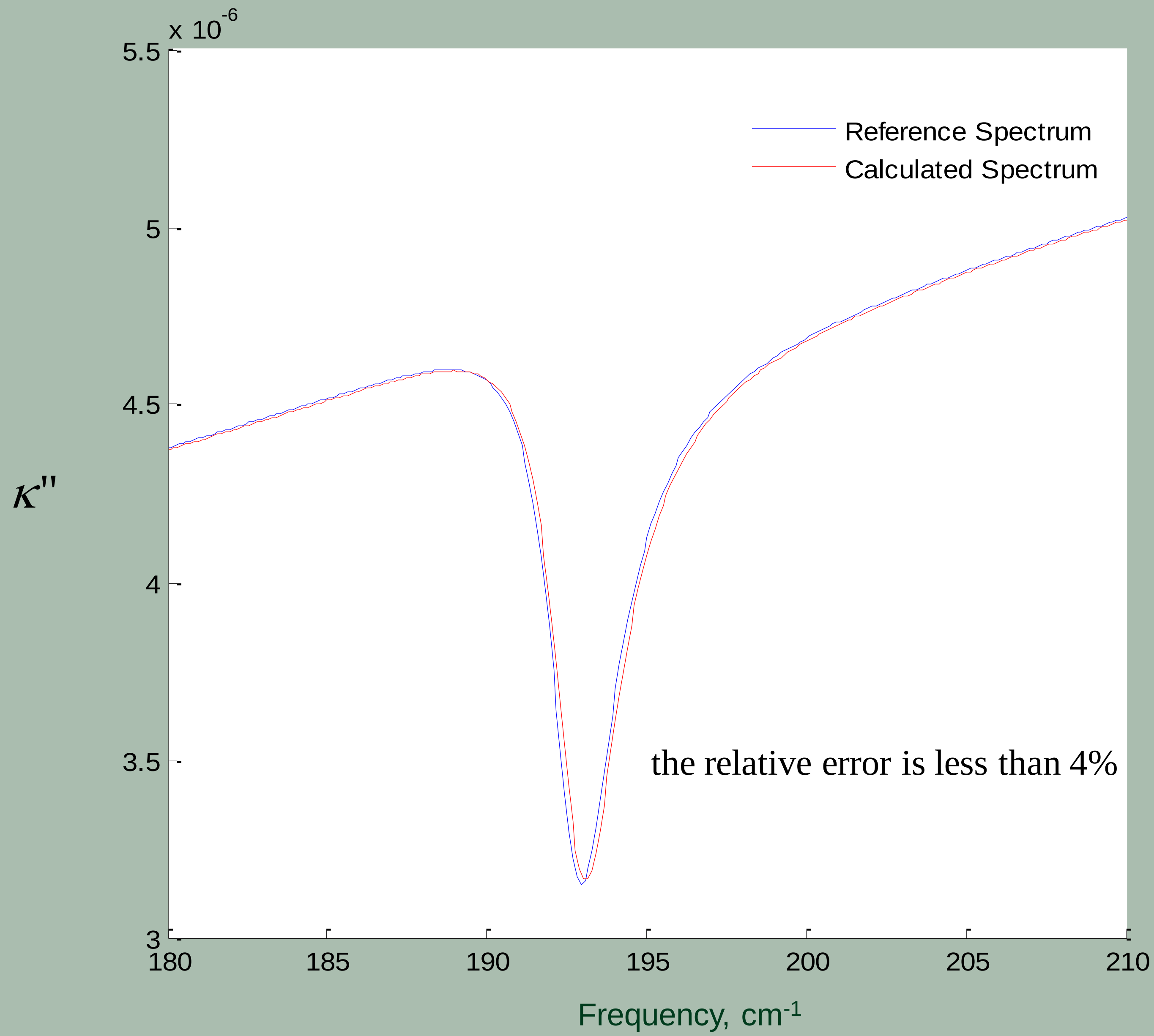
$$\kappa''_{\nu j} = \frac{1}{2k_{ov\,j} \Delta l} \cdot \ln \sqrt{\frac{\left(C_{\nu j}^{2} + S_{\nu j}^{2} \right)_{l_1}}{\left(C_{\nu j}^{2} + S_{\nu j}^{2} \right)_{l_2}}}$$

Example of an interferogram calculated for the dynamic THz SP Fourier spectrometer



Calculation parameters: N=8000, *a*=5 см, *b*=5 см, *x*=5 см, sampling step d*x*=10.0 мкм

Comparison between the original spectrum of imaginary part κ″ of the SP refractive index and the one defined by the SP Fourier spectrometer



Thank you