The Cryogenic Nanosensors Workshop, Björkliden, Kiruna, Sweden, March 20-27, 2011

The peculiar THz features of surface electromagnetic waves

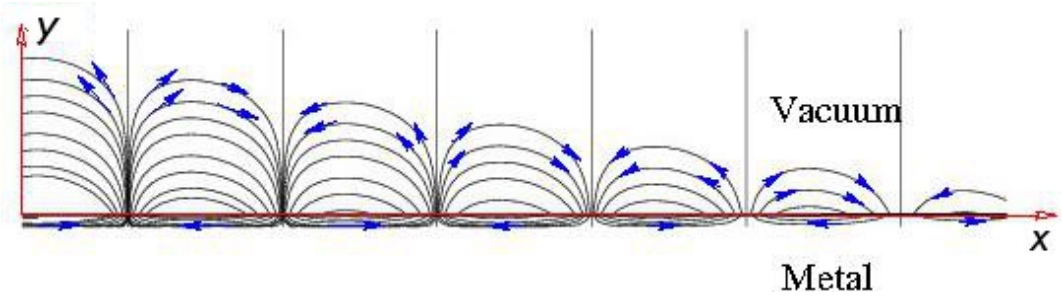
V.V. Zavyalov

P.L. Kapitza Institute for Physical Problems Kosygina 2, Moscow, Russia;

- V.S. Edelman, I.I. Smol'yaninov, and V.V. Zav'yalov, *Spectroscopic measurements of light emitted by scanning tunneling microscope.* Phys. Lett. **A158**, pp.337 (1991)
- G.D. Bogomolov, Uk Young Jeong, G.N. Zhizhin, A.K. Nikitin, V.V. Zavyalov, G.M. Kazakevich and Byung Cheol Lee, *Generation of surface electromagnetic waves in terahertz spectral range by free-electron laser radiation and their refractive index determination.* Nucl. Instr. & Meth. in Phys. Res. **A 543** p.96 (2005)
- G.N. Zhizhin, A.K. Nikitin, G.D. Bogomolov, V.V. Zavialov, Jeong Young Uk, Lee Byung Cheol, Seong Hee Park and Hyuk Jin Cha, *Absorption of surface plasmons in a metal-cladding layer-air structure in the terahertz frequency range.* Optics and Spectroscopy **100**, No.5, pp.734-738 (2006)
- Zhizhin G.N., Nikitin A.K., Bogomolov G.D., Zavyalov V.V., Jeong Y.U., Lee B.C., Park S.H., Cha H.J., *Aluminum optical constants in the far infrared determined from surface electromagnetic waves characteristics.* Proc. SPIE, 2006, v.6162, Art. 61620C.

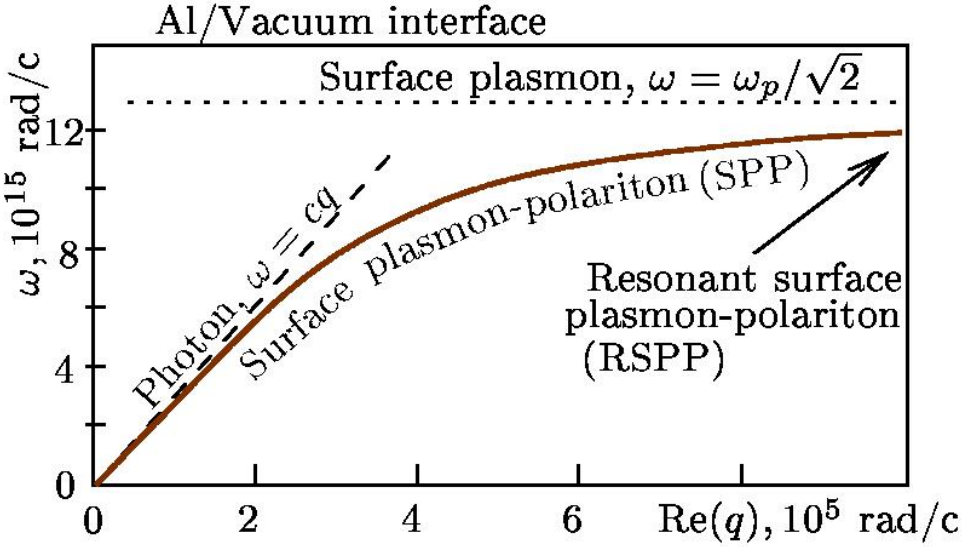
SEW is an evanescent-field solution of Maxwell's equations

$$\text{rot}\,\mathbf{E} = i\,\frac{\omega}{c}\,\mathbf{B}\,, \quad \text{rot}\,\mathbf{B} = \frac{4\pi}{c}\,\sigma\mathbf{E} - i\,\frac{\omega}{c}\,\varepsilon\,\mathbf{E}\,, \quad \text{div}\,\mathbf{B} = 0\,, \quad \varepsilon = \varepsilon' + i\varepsilon''$$



$$E_{\text{vac}} \sim e^{i\omega t + qx + k_{\text{vac}}\, z}$$

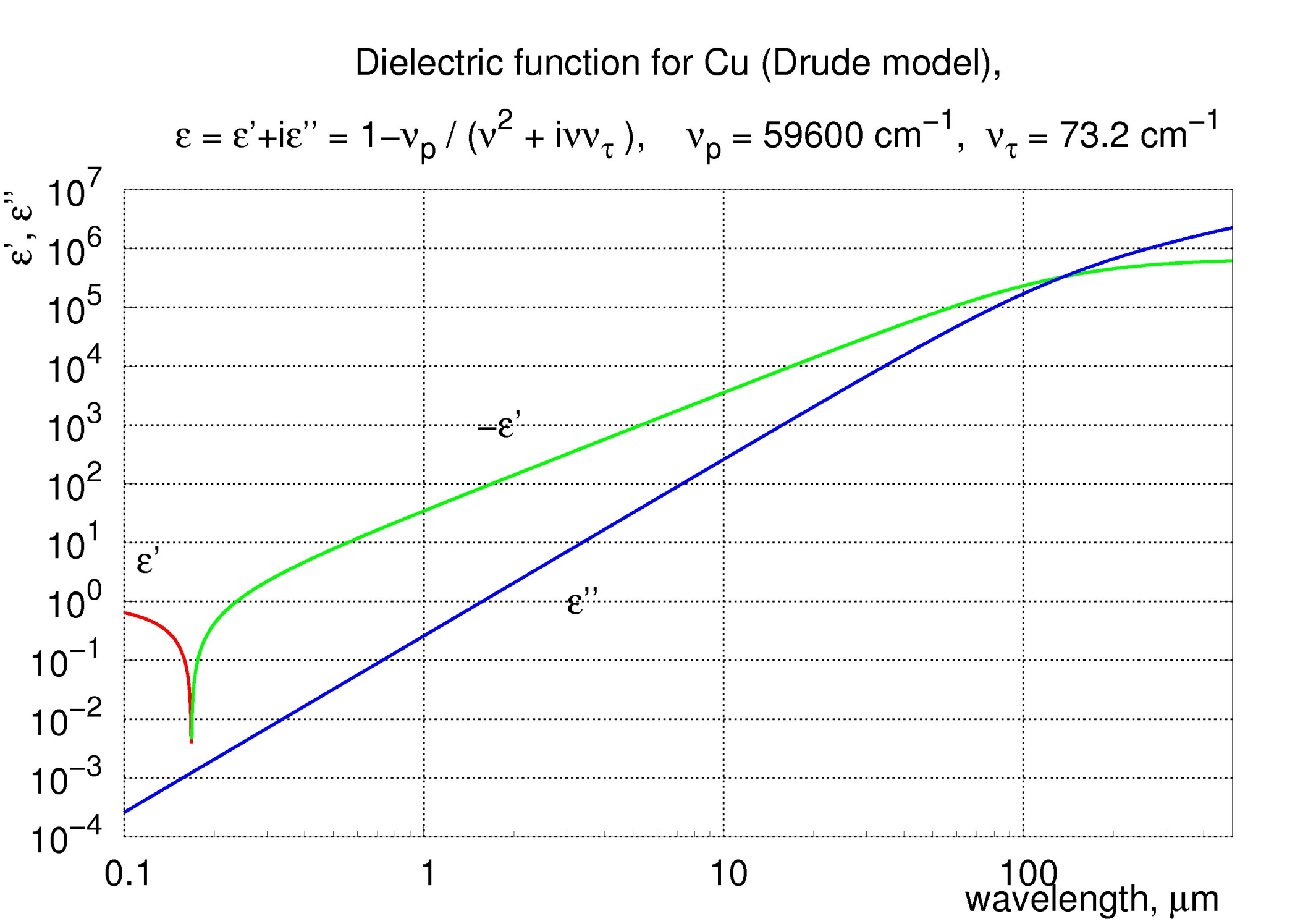
$$E_{\text{met}} \sim e^{i\omega t + qx + k_{\text{met}}\, z}$$



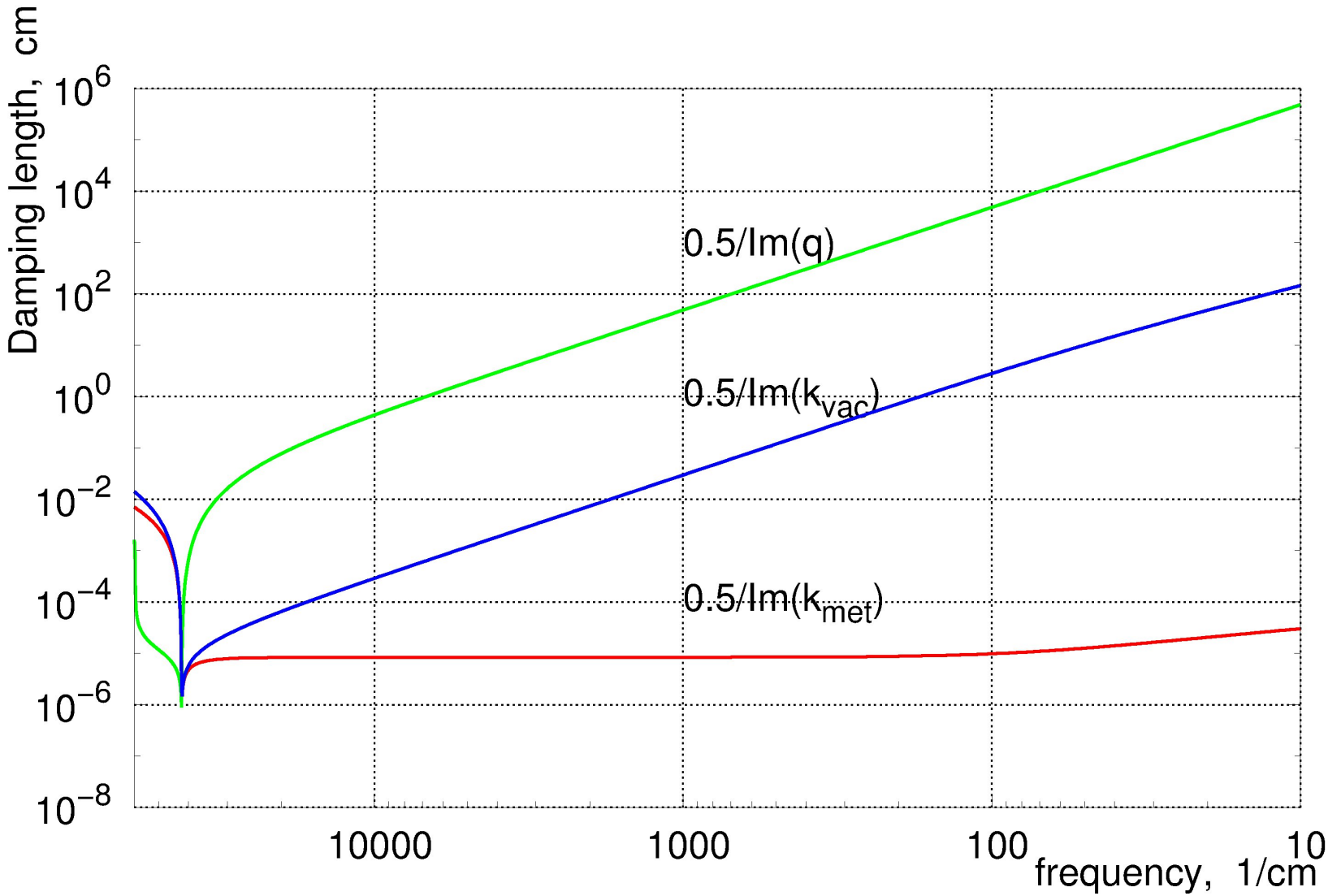
$$q = k_0\sqrt{\frac{\varepsilon}{1+\varepsilon}}$$

$$k_{\text{vac}} = \frac{q}{\sqrt{\varepsilon}}$$

$$k_{\text{met}} = \sqrt{\varepsilon}\,q$$

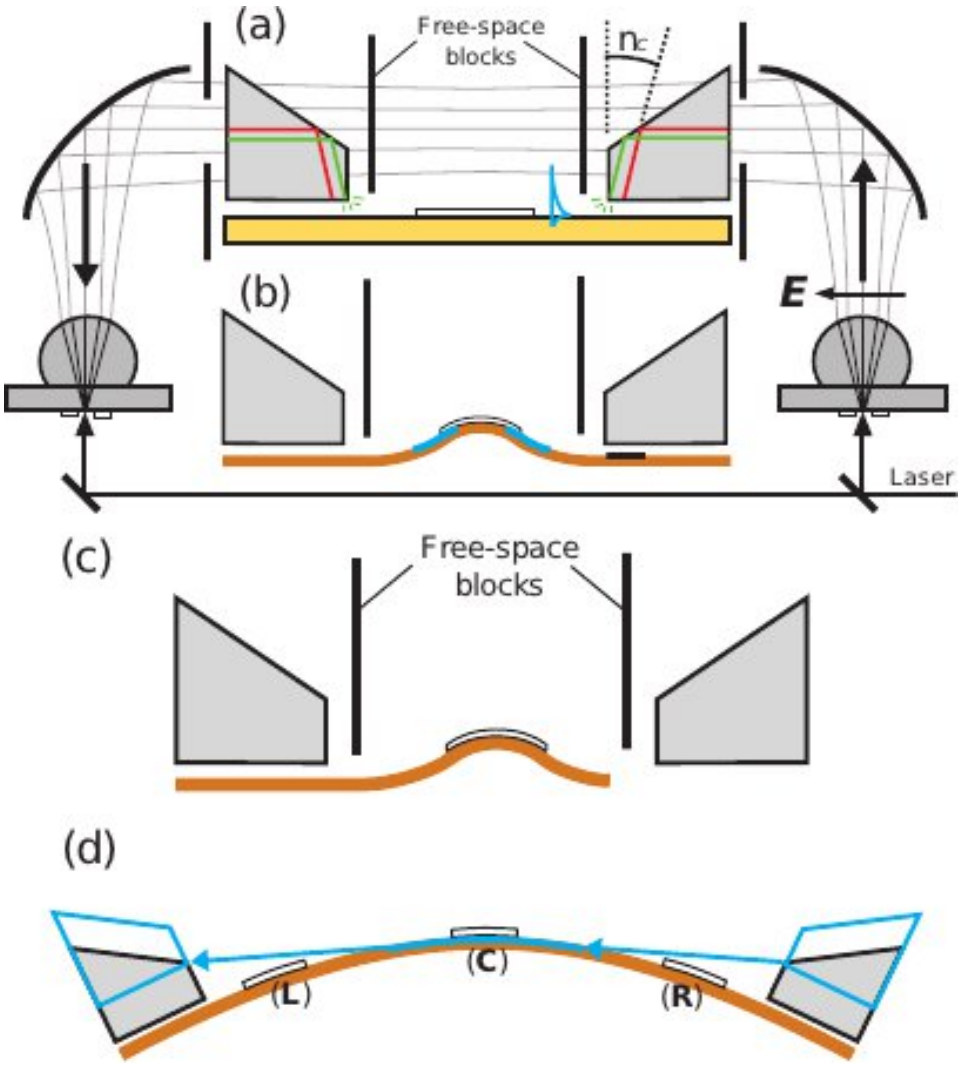

Dielectric function for Cu (Drude model),
ε = ε'+iε'' = 1−ν_p / (ν^2 + iνν_τ), ν_p = 59600 cm^−1, ν_τ = 73.2 cm^−1
ε', ε''
10^7
10^6
10^5
10^4
10^3
10^2
10^1
10^0
10^−1
10^−2
10^−3
10^−4
−ε'
ε'
ε''
0.1
1
10
100
wavelength, μm

Damping lengths for Al

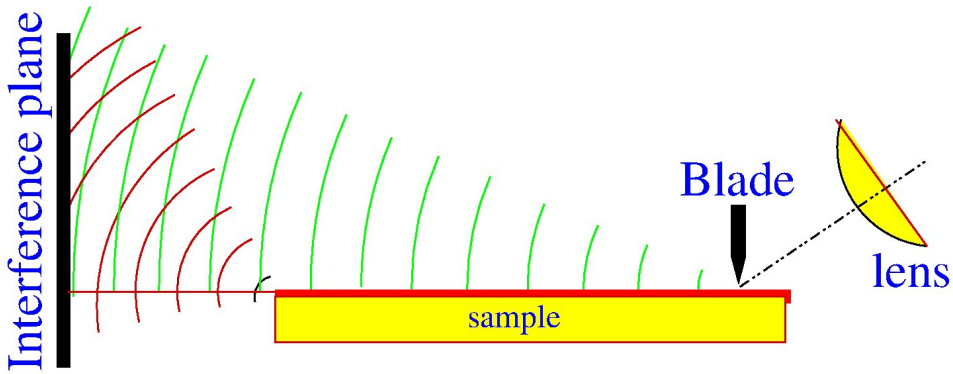


experimental observation of THz SEW

J F. O'Hara, R D. Averitt, A. J. Taylor
Opt.Express **13**, 6117 (2005)

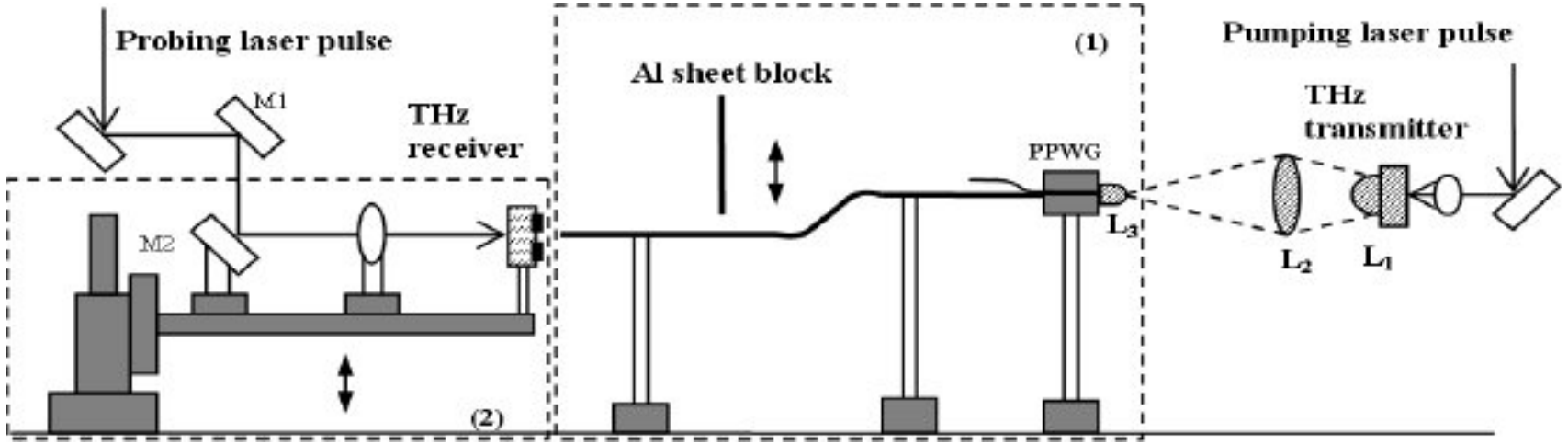


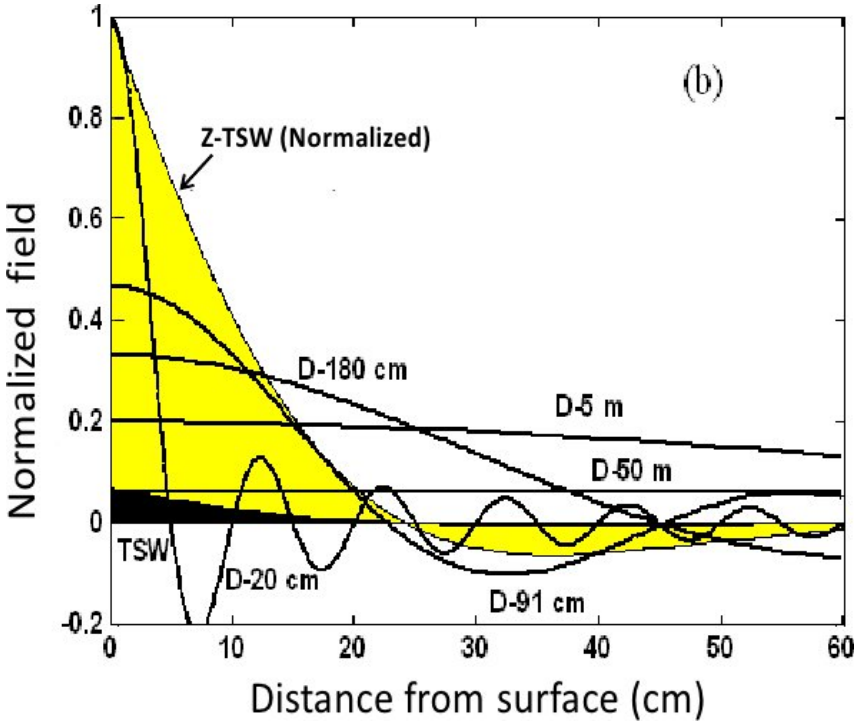
KAERI experiment layout

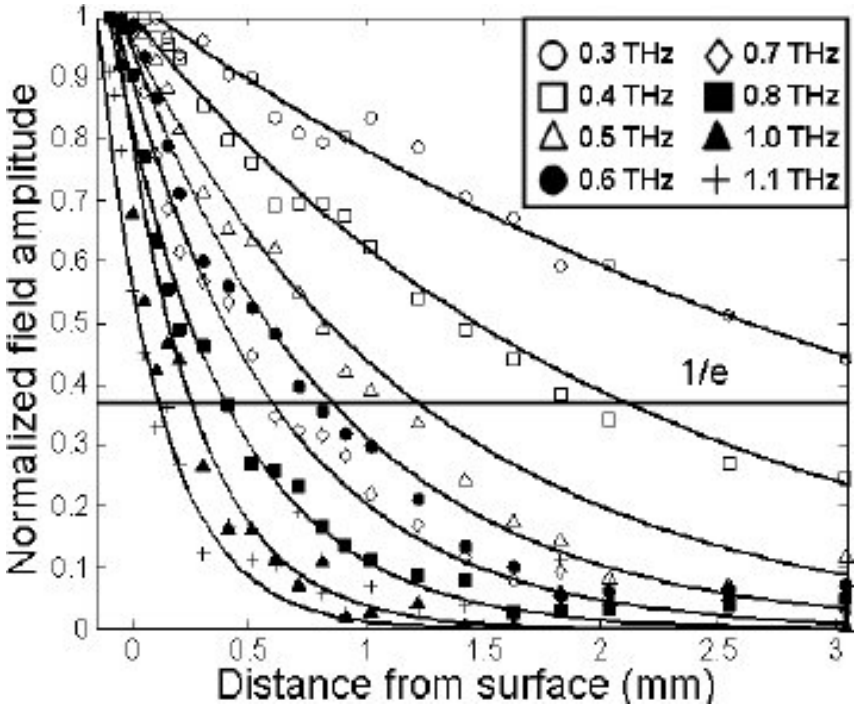


experimental observation of THz SEW–continue

Mufei Gong1, Tae-In Jeon2, D. Grischkowsky, Opt.Express**17**, 17088 (2009)



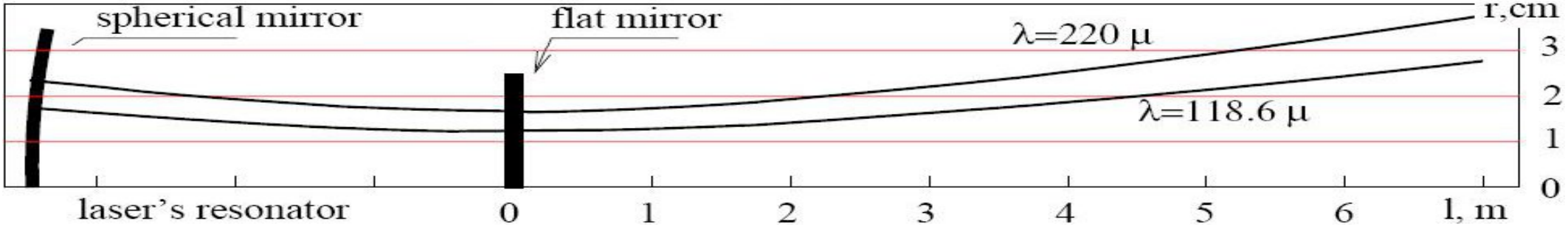


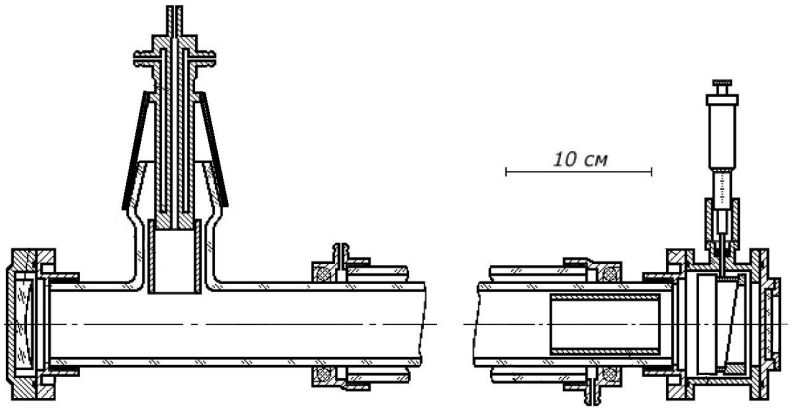


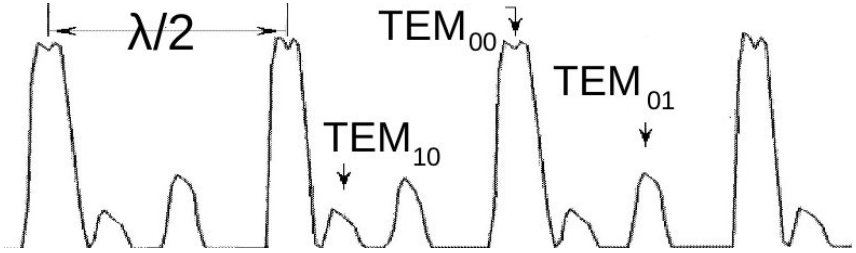
H_2O laser

H_2O+H_2: 220.2, 118.6, 79.1, 78.4, 55.1, 33, 28μm;

D_2O+D_2: 171.7, 107.1, 84 μm



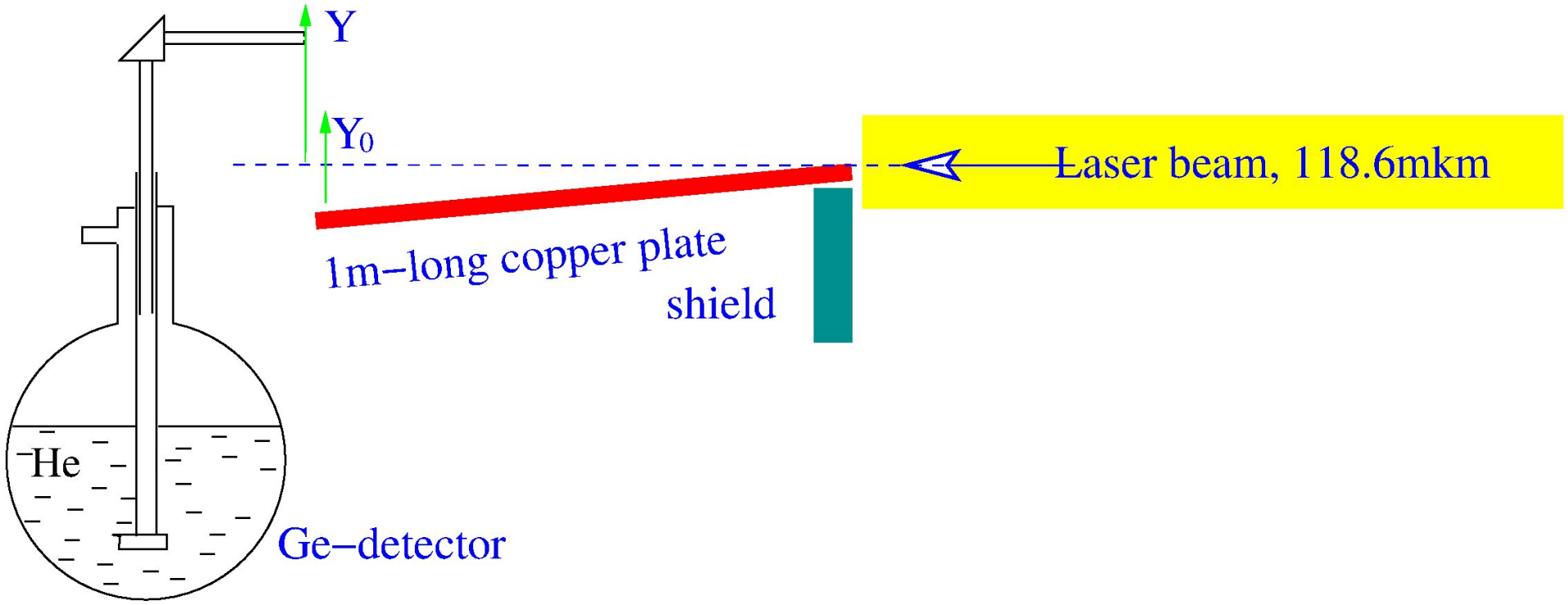




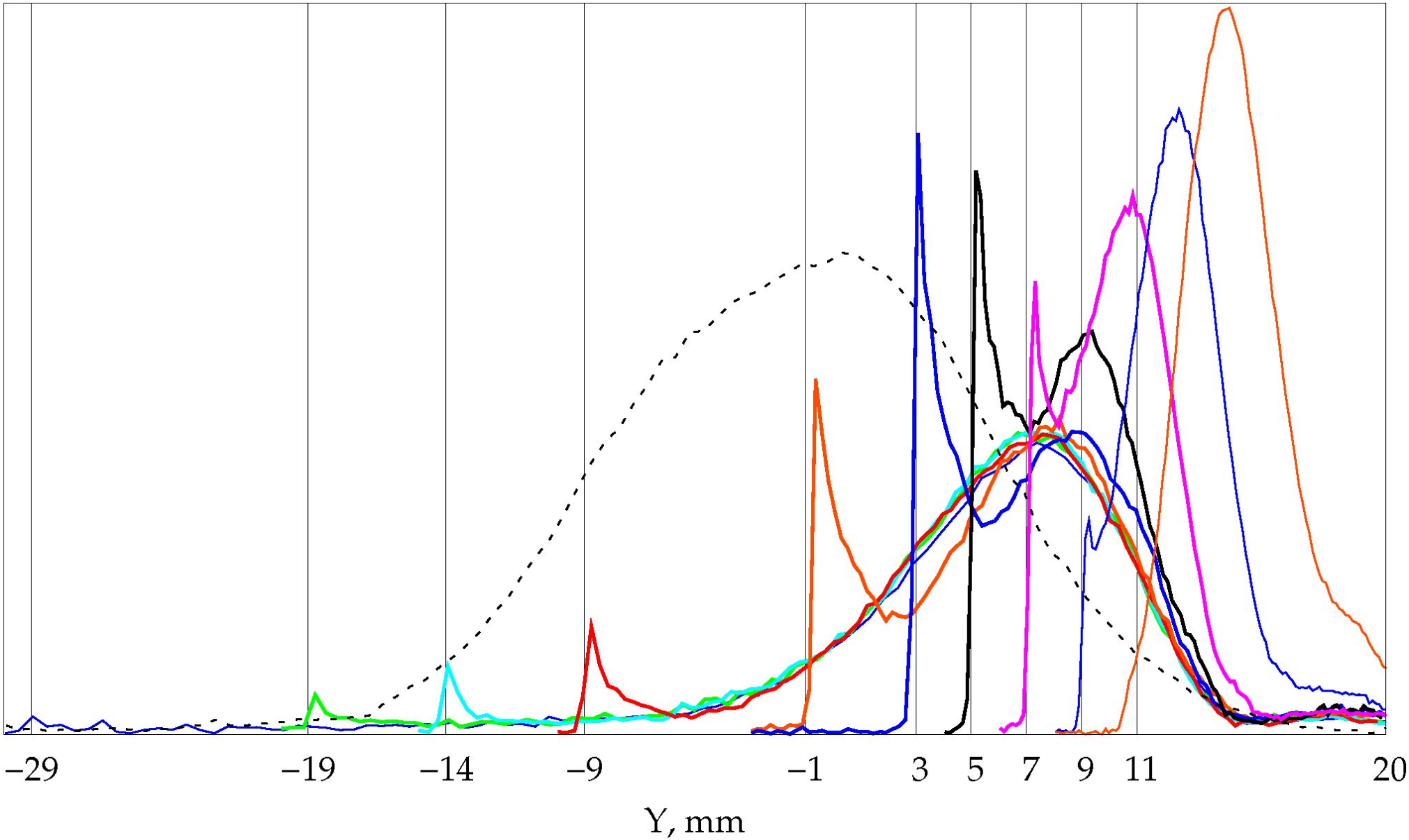
Zavyalov V.V., Dissertation. KIPP, Moscow 1976

Our new experimental setup

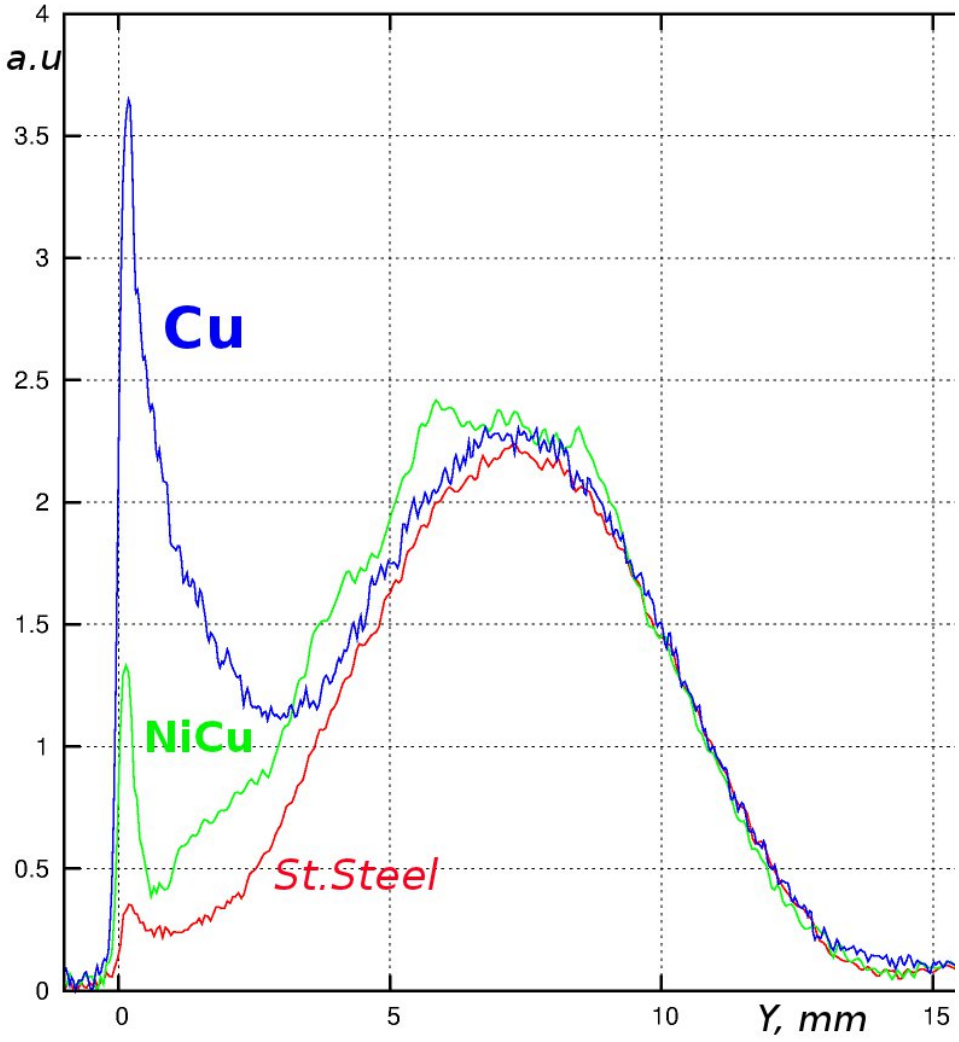
to measure Thz-beam cross-section at the end of the long copper plate

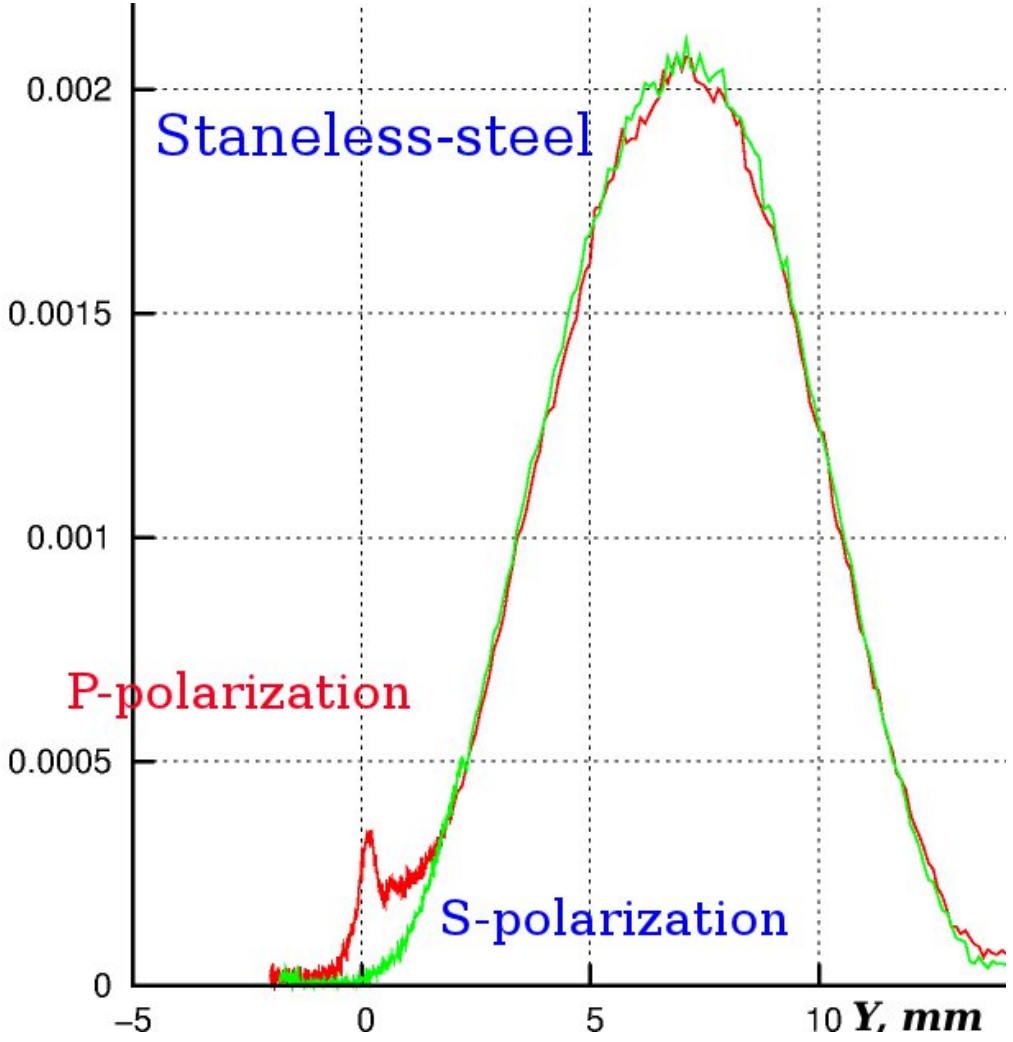


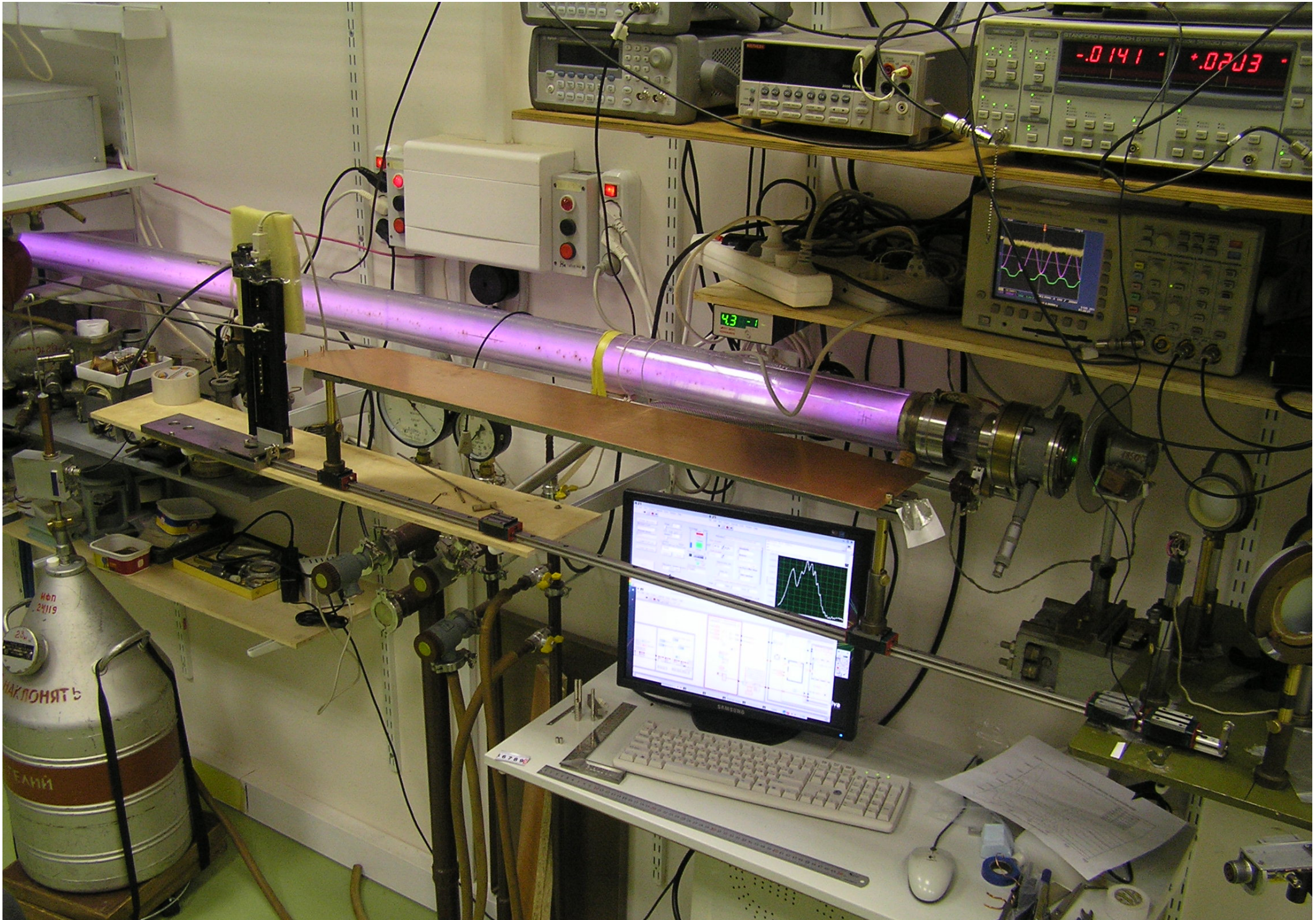
Thz-beam cross-section at the end of the long copper plate

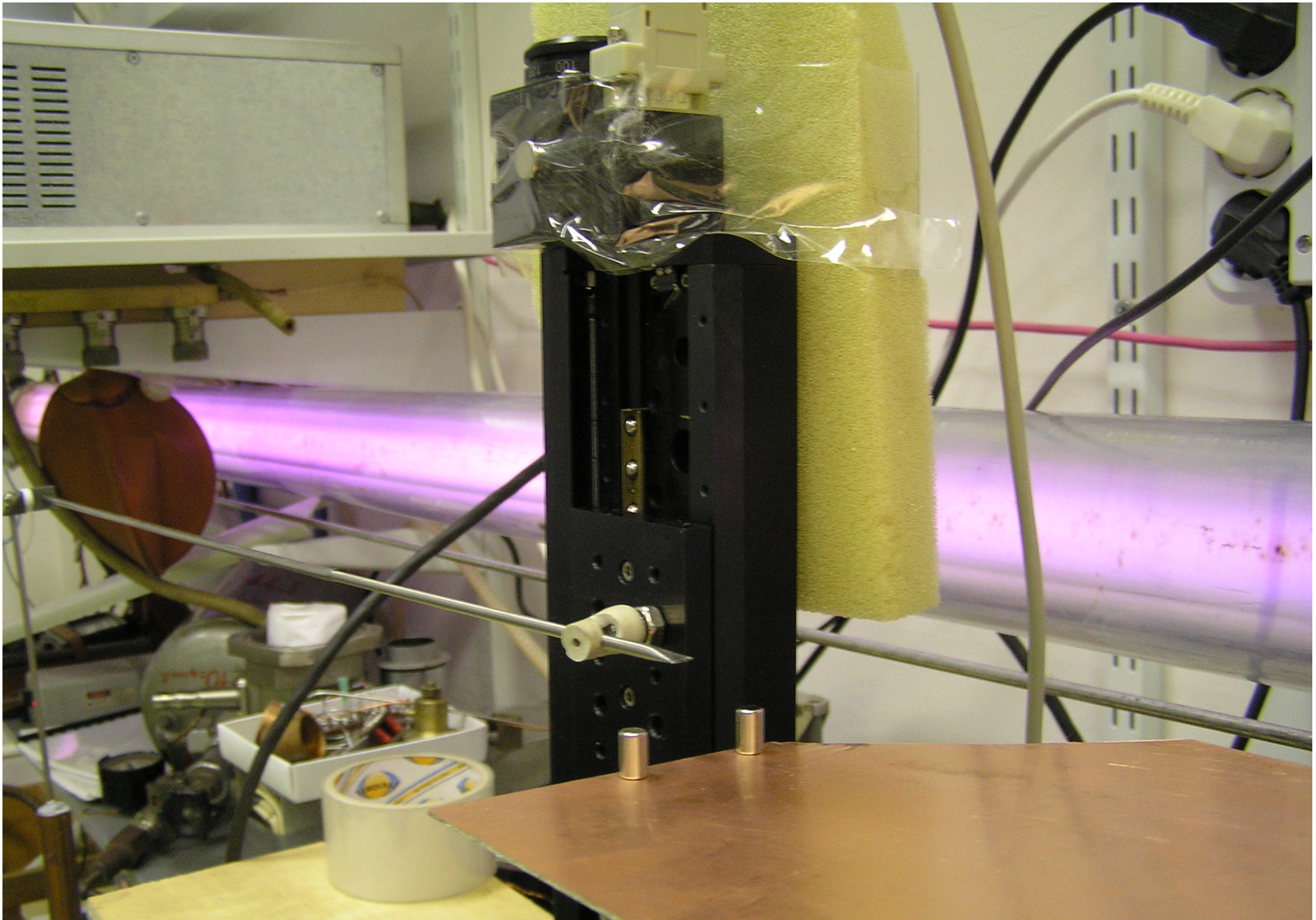


Metal-dependant and polarization-dependant effects






-.0141
+.0203
4.3 -1
SAMSUNG



RESULTS

- High-efficient exitation of THz-SEW on metal was achieved.
- The exponential damping of THz-SEW above bare metals was measured, and it agree well with the theory.
- Found, that under the THz-region the difference of longitudional fase-velosities of SEW and free EM-wave are of no importance:
  - fase-matching couplers and decouplers are useless;
  - stand-alone SEW not possible;
  - to exite the SEW with the light beam, one has to match once their EM-field distributions.