Transmission of a focused THz pulse trough a pinhole

1. Calculated THz beam waist diameter $2w_0$

The diameter of the beam focus $2w_0$ depends on the THz frequency f and can be estimated in case of a Gaussian beam using the relation

$$2w_0 = \frac{4}{\pi}\lambda\frac{f_L}{D} = \frac{4}{\pi}\lambda \cdot F^* = \frac{4}{\pi}\frac{c}{f}\frac{f_L}{D} = \frac{4}{\pi}\frac{c}{f}\cdot F^* \text{ with } \qquad F^* = \frac{f_L}{D} \qquad (1)$$

Here f_L is the focal length and D the diameter of the focusing THz lens or the diameter of the collimated beam. Besides the terahertz wavelength λ or frequency f the F* number of the lens determines the beam focus diameter $2w_0$. c is the speed of light in vacuum.

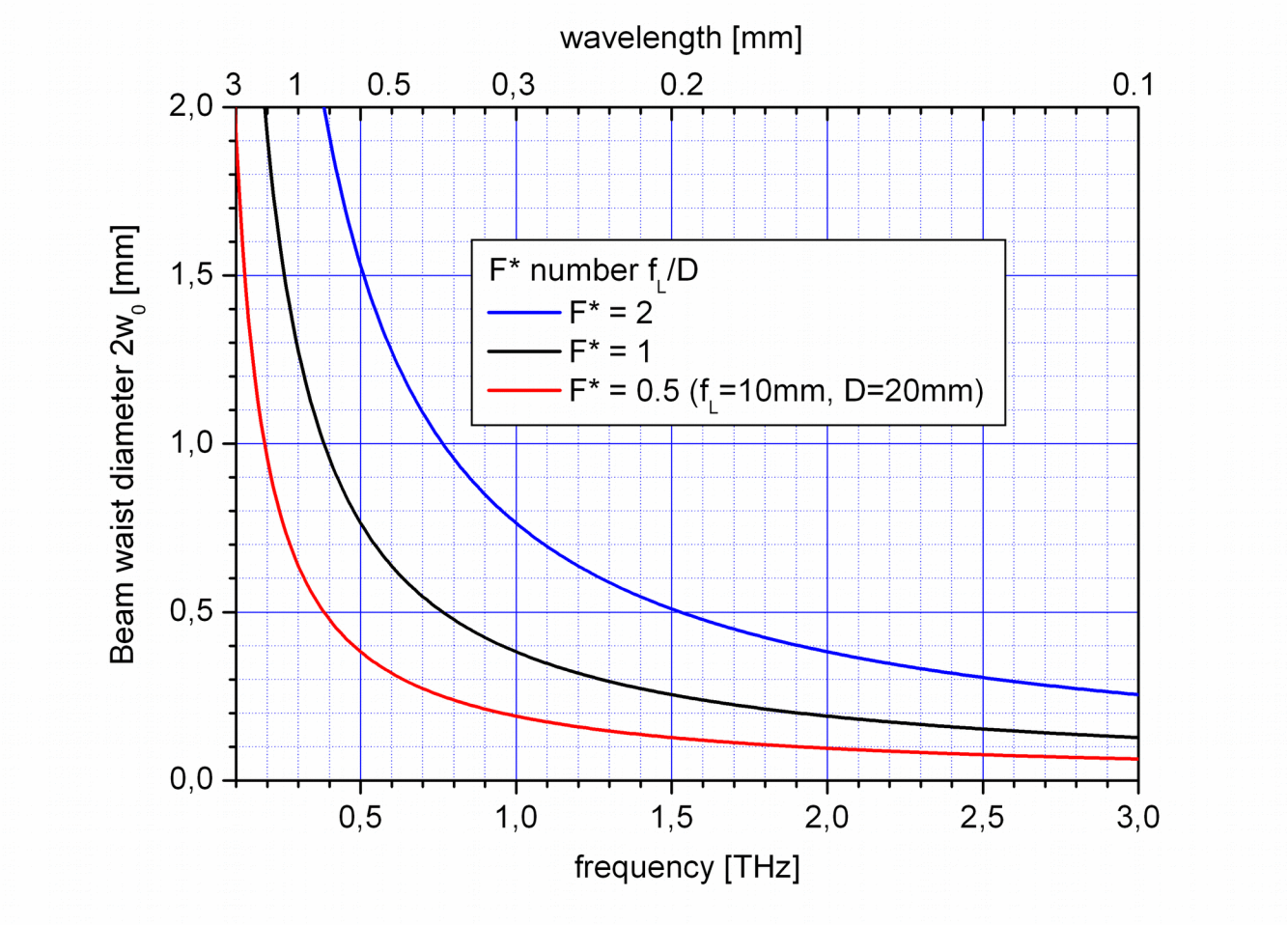


Figure 1: Calculated focus diameter $2w_0$ as a function of THz frequency according to equation (1)

2. Measurement set-up

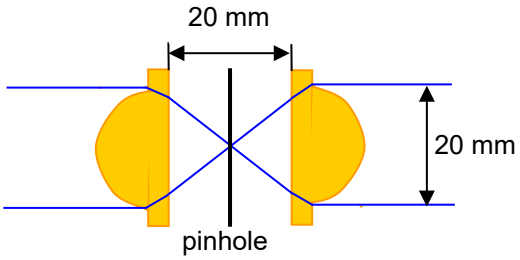
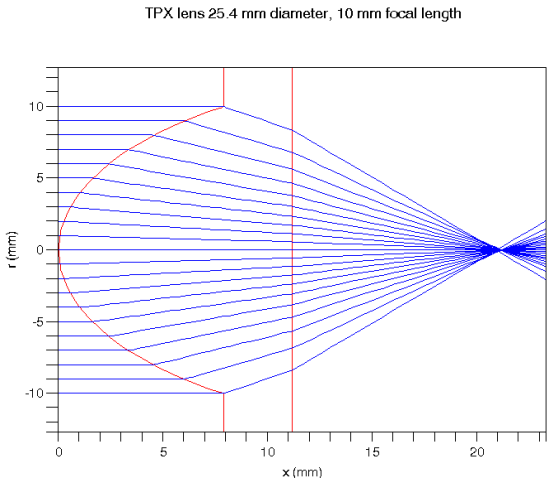


Fig. 2 Measurement setup



Focusing TPX lenses: Focal length f_L =10 mm
Free aperture diameter D = 20 mm
Lens thickness 10 mm
Aperture angle ~ 40 °

Collimated THz beam diameter: 20 mm → F* = f_L/D = 0.5

Pinhole: Al-sheet with hole diameters: 0.35 mm, 0.5 mm, 0.6 mm, 0.8 mm, 1.0 mm, 1.5 mm, 2.0 mm

3. Transmission measurements through pinholes (F* = 0.5)

The THZ pulse contains a broad spectrum. The pinhole woks as high pass filter.

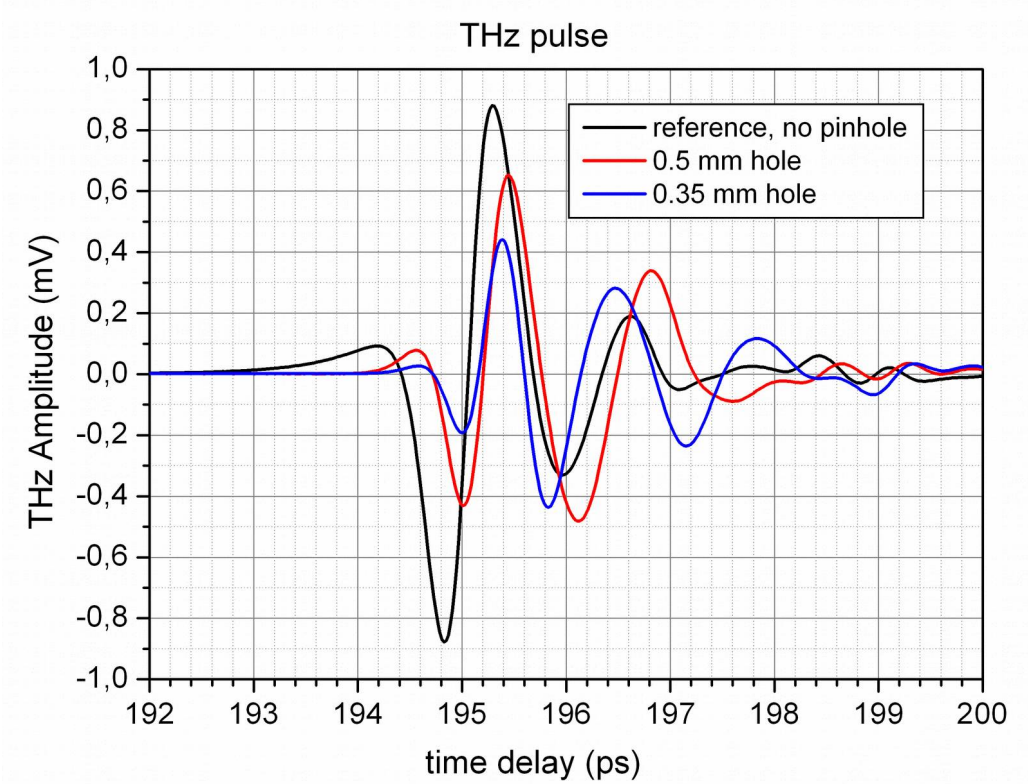


Fig. 3: Measured pulse amplitude after pinholes with diameter 0.5 mm and 0.35 mm

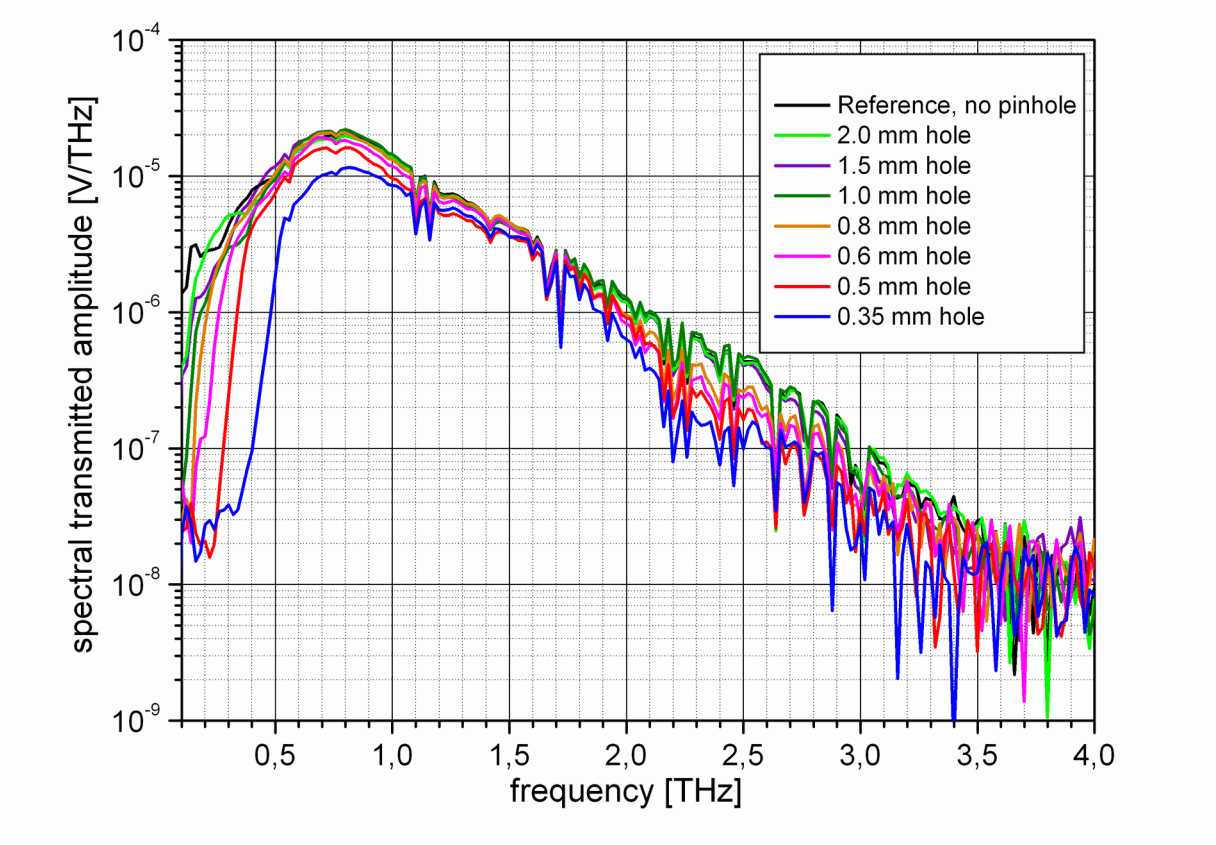


Fig. 4: Measured spectral transmission trough pinholes with different hole diameters. F* = 0.5

4. Discussion of the results

The measured cut-off frequency in the transmission curves (fig. 4) corresponds to calculated frequencies according to equation (1) (red curve in fig. (1)).

The perfect agreement between the calculated and diffraction limited focus diameter is only possible when the following experimental conditions are fulfilled:

a) No spherical aberration of the used focusing lenses. → Use of elliptic TPX lenses.

b) The focusing lenses and the pinhole are perfect aligned. → Two xyz-stages for fine adjustment of the lens distance and pinhole position has been used in the experiments..

→ By using aspheric TPX lenses with F* = 0.5 in the frequency region 1 .. 3 THz a spatial resolution of about 300 µm is possible.