Terahertz Leaky-Wave Mediated Quasi-Optical Filters

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Given the increase of dielectric and conductive losses at THz frequencies (ca. 0.3 – 10 THz) compared to microwaves, THz technology has relied strongly on free-space quasi-optics (G. Carpintero *et al.*, Semiconductor TeraHertz Technology: Devices and Systems at Room Temperature Operation, Wiley-IEEE Press, 2015). Hence, frequency selective surfaces (FSSs) are widely used at THz frequencies. Subwavelength hole arrays supporting the so-called extraordinary transmission (ET) have been proposed as an alternative to traditional FSSs. ET is related to the periodic nature of the array rather than to the single element geometry itself as in FSS. One should expect a strong dependence on the fabrication and the experimental conditions (e.g., illumination beam-waist). These dependences should be investigated comprehensibly to assess the applicability of subwavelength hole arrays as quasi-optical filters.

Narrowband filtering with 0.04 dB insertion loss and 10 dB out-of-band rejection level is achieved here by electroforming fabrication of freestanding resonant subwavelength hole array matrices whose perforated area is significantly larger than the beam spot of a collimated THz beam (see Fig. 1). The need of large subwavelength hole arrays and collimated beams is traced to the leaky-wave mechanism supported by the resonant hole array. Experimental characterization of aluminum (with 20 μm polypropylene substrate – contract photolithography fabrication) and copper (freestanding – electroforming fabrication) samples of varying hole matrix size is done by high-resolution continuous-wave quasi-optical backward wave oscillator and THz time-domain spectroscopy techniques. The use of different setups allows us to vary the beam spot upon the sample from collimated (beam waist ϖ_0 = 12.5) and 5 mm) to focused beams (ϖ_0 = 3, 1.5 and 1 mm) at the frequency of operation. Measurements are supported by CST Microwave Studio® full-wave simulations of infinite and finite resonant subwavelength hole arrays. The center frequency of the bandpass filters falls within the ALMA bands #8 and #9.

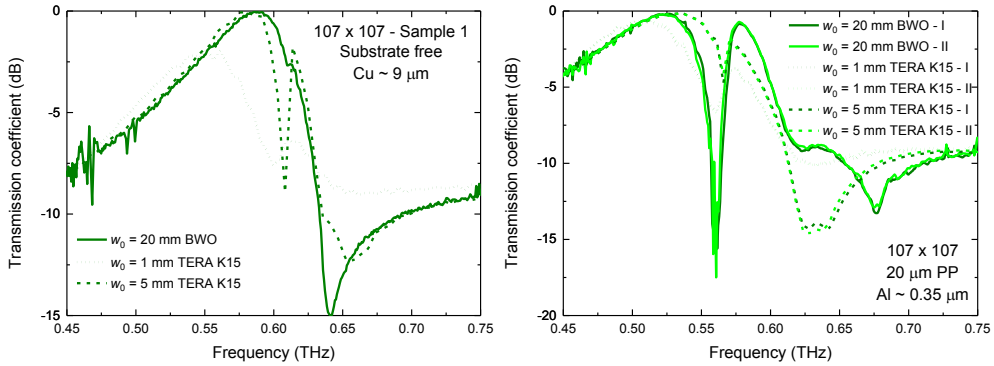

Figure 1. Measured transmission coefficient for Cu (left) and Al (right) samples with 107 holes × 107 holes when a THz beam with beam-waist 1 mm, 5 mm and 20 mm illuminates them.