THz imaging Objective Design with fixed back focal distance for medical applications

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A novel reflective THz imaging objective mirror design is presented and characterized that can switch between pairs of numerical aperture and focal length while maintaining a fixed back focal distance (BFD). This allows the user to easily explore the effect of varying spot size, depth of field and working distance paremter during medical imaging studies without the need for optical realignment. The objective assembly design employs conjugate pairs of off axis parabolic (OAP) mirrors that accept and output parallel, collimated beams. Three pairs of effective focal length (EFL) mirrors were evaluated using a pulsed THz imaging system operating at an effective center frequency of 525 GHz with 125 GHz of 3 dB bandwidth. For the 25.4 mm 50.8 mm, and 76.2 mm EFL mirror pairs, the objective mirror design achieves a 10%-90% edge response measurements of 0.6 mm, 1.3 mm, and 2.1 mm and depth of field of 0.86 mm, 4.0 mm, and 11.7 mm, respectively. Investigation of the propagation of Gaussian THz beam profile from the photoconductive source, through the objective, and to the detector are presented. The knife-edge measurements agree with the predicted focused illumination spot size at the target and the predicted power at the detector focal plane, suggesting the entirety of focused THz beam profiles are effectively captured at the detector plane. Furthermore simulations show that the beam spot walks away from the detector aperture in the detection plane as the target plane is moved in and out of the system focal plane. This suggests that the system is operating in a regime that resembles confocal optical setup. Additionally, the off-axis distortion of field energy distribution and introduction of cross-polarization components is analyzed and the differences to optimal configurations analyzed. We conclude that the deviation of our systems optical setup from the optimal "ortho" conjugate configuration results in minimal degradation in optical performance. This suggests that OAP mirror setups can be designed to maximize practicality with marginal reductions in performance.