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Gradient-index Silicon Optics for Millimeter-wave detectors

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For quasi-optical elements in the millimeter and sub- millimeter range, silicon is an interesting material. Its high refractive index facilitates the production of compact and lightweight elements. Moreover, its thermal conductivity allows better thermalisation at cryogenic temperatures, and the loss tangent of bulk high-resistivity silicon (tan δ < 10- 4) is without competition.

Silicon is however very difficult to machine, and the high refractive index necessitates the use of anti-reflection coatings. Micromachined anti-reflection coatings have been developed for planar substrates but become increasingly more difficult for curved surfaces of e.g. lenses.

In this work, we follow a different approach. We use the fact that it is possible to modulate the refractive index of a material by inserting sub-wavelength voids and changing the fill factor of the voids. This way, a silicon metamaterial with a dielectric constant between 3.3 and 11.7 can be generated.

We describe our efforts to generate optical elements from thus modulated silicon, in particular the characterisation of a planar silicon lens with integrated anti-reflection coating. The presented technology offers great perspective in terms of compact, planar, low-loss optics. Moreover, the technology can be easily integrated with silicon detector wafers, and future developments that involve more elaborate anti-reflection coatings, integrated filtering, or microlens arrays, are just part of the possibilities.

Less than 5 years of experience since completion of Ph.D

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