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Flat low-loss silicon gradient index lens for millimeter and submillimeter wavelengths

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Many applications in astronomy from tens of GHz to THz frequencies, such as CMB polarization studies and Sunyaev-Zeldovich effect observations, would benefit from low loss and wide bandwidth optics. Silicon is an excellent material for optics within this frequency range because of its high refractive index, achromaticity, lack of birefringence, low loss, high thermal conductivity, and strength.

Silicon's high index, however, presents a challenge for antireflection (AR) treatment, which our approach addresses. Its two core elements are: 1) fabrication of multi-layer AR structures via multi-depth deep reactive ion etching (DRIE) and wafer-bonding; and 2) assembly of gradient index (GRIN) optics, flat-faced to be consistent with AR treatment, by bonding multiple silicon wafers patterned with the desired radial index profile by DRIE. Both the AR structures and the GRIN structures are made of sub-wavelength features (posts or holes) that change the effective refractive index of silicon. For AR structures, each AR layer has a different homogeneous index while for GRIN lenses, the index varies radially (higher in the middle and lower near the edge of a focusing lens). Moreover, GRIN lens design only uses holes so it can be physically continuous and thus edge-mountable. To reach the desired GRIN lens thickness, several identical etched wafers must be bonded together because we cannot use DRIE to etch vertical holes deeper than a few hundreds of µm with a high aspect ratio (up to approximately 20:1).

We present our results to date, which include the design, simulation, fabrication and measurement of a 100 mm diameter flat GRIN lens made of high resistivity silicon, combined with single- or double-layer AR structures, centered on 250 GHz.

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

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