Beyond isotropy of cubic crystals

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The dielectric response of cubic crystals, like Si, Ge, GaAs, InSb, and CaF_2, is commonly assumed to be isotropic. This assumption stems from the fact that, at optical frequencies, the wavelength of light is much larger than characteristic distances inside the crystal (usually of the order of interatomic distances), $a/\lambda \ll 1$. Within this limit, the macroscopic material response is local. This description breaks down mainly in the spectral region near excitations, where the refractive index increases and the ratio a/λ becomes non-negligible. Keeping non-local terms in the dielectric tensor explains the weak anisotropy observed in cubic crystals [1]. The intrinsic birefringence has caused many problems in the semiconductor industry, where cubic crystals are widely used as substrates for layer growth. Substrate anisotropy can make optical characterization of the layers challenging. Another example is the failure of 157nm lithography, where the crystals used for UV laser optics, CaF_2 and BaF_2, exhibit unacceptably large birefringence [2].

In this work, we utilize high-sensitivity Mueller matrix polarimetry to measure the weak anisotropy of cubic crystals. This approach has recently been shown to work well for reflection measurements on silicon [3]. We also present our transmission experimental results that show intrinsic birefringence of Si and CaF_2. In addition, we demonstrate the directional dependence of the intrinsic birefringence by examining crystals with different surface orientations. Rotational symmetries of the crystal axes are clearly visible (Fig. 1), indicating that the measured birefringence is intrinsic and not induced, e.g. by strain.

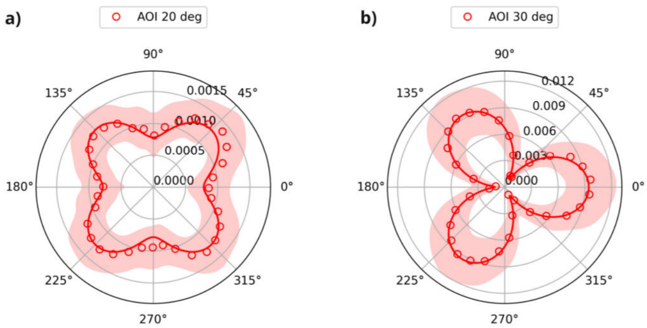

Fig. 1. Intrinsic linear birefringence of silicon at λ=1000 nm as a function of rotation angle about the surface normal for **a)** (001) and **b)** (111) surface orientations, measured in transmission.

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