Contribution ID: **74**

Type: **poster**

Birefringence measurements of silicon substrates

To reach the sensitivity requirement of Einstein Telescope for gravitational waves detection, the birefringence of optic substrates must be optimised. The intrinsic birefringence of such substrates mainly comes from internal stress within the material, but can also be induced externally (by optical mounts for instance).
The Ferrara ET Research Unit has been working on 2D birefringence maps of substrate candidates in transmission at 1550 nm, using a highly sensitive optical polarimeter. These maps will be presented during the annual meeting.

The birefringence Δn of a given sample of thickness D induces a time dependant ellipticity such as $\psi(t) \approx \pi/\lambda \Delta n D sin 2\theta(t)$ where $\theta(t)$ is the time-dependant angle between the polarisation of the beam and the birefringence axis.
The scheme of the polarimeter in transmission is composed of two half-wave plates co-rotating at ν_w, in between which there is the sample to be measured and a 2.5 T magnetic field rotating at ν_B (for calibration). When a linearly polarised beam passes through the first waveplate, a time-dependant ellipticity $\psi(t)$ is generated in the sample, which is then stopped by the second waveplate. Then, a known ellipticity $\eta(t)$ is introduced by a photo-elastic modulator followed by an analyser placed at maximum extinction. The modulator ellipticity allows to linearise the ellipticity with the output power $P_{out} = P_0(\eta(t) + \psi(t) + ...)^2 \approx P_0(\eta(t)^2 + 2\eta(t)\psi(t) + ...)$.
By demodulating at $4\nu_w$, it is possible to extract the ellipticity induced by the sample. Additionally, the Cotton-Mouton of air at $4\nu_w \pm 2\nu_B$ is used for zero measurements.

2D ellipticity maps are obtained using a 2D automated translation system. By normalising \Delta n by the given sample's thickness, we finally obtain 2D birefringence maps.
During this annual meeting, we will present maps of few mm thick mono-crystalline (100) and (110) silicon samples of birefringence of the order of 2×10^{-7} and 1.5×10^{-6} respectively. More recent maps of larger silicon sample (2inch diameter) will also be discussed for which a birefringence of a few 10^{-8} was measured.

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Session Classification: Poster Session

Track Classification: ISB: Optics