

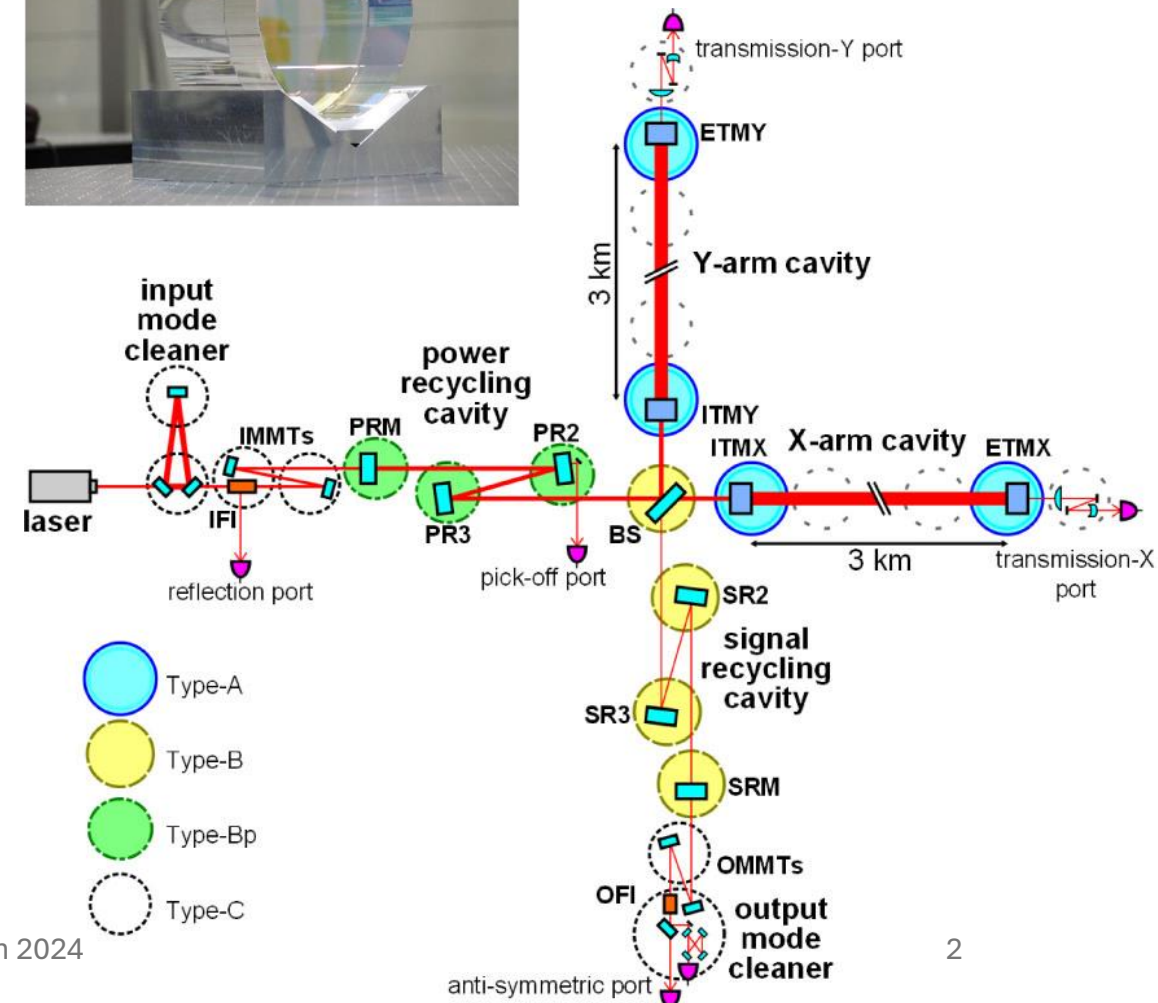
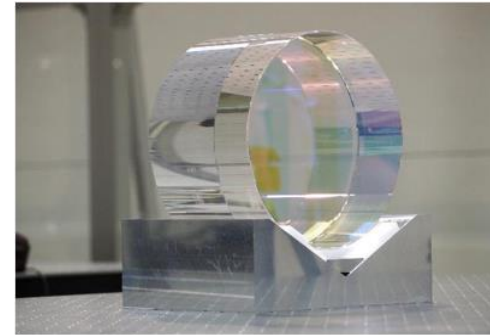
Update on KAGRA sapphire substrates

Marc Eisenmann on behalf of KAGRA MIR group



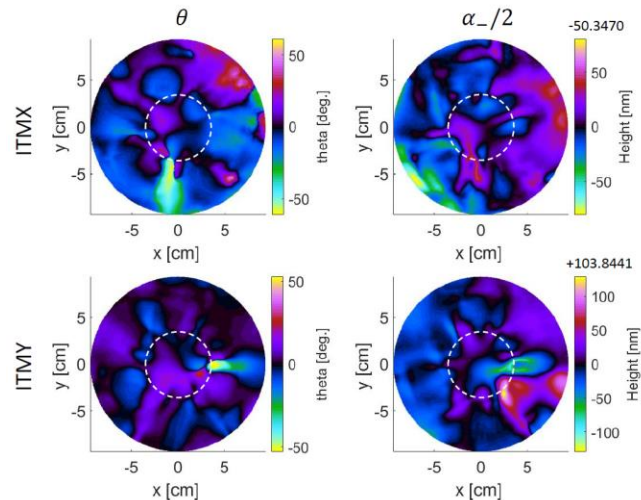
KAGRA configuration

- KAGRA will operate as DRFPMI with sapphire test-masses cooled down to 20K.
- Current test-masses are 23kg, 22cm diameter and 15 cm thickness
- The sapphire substrates are cut to have the c-axis aligned with the optical axis within 0.2 deg
- The substrate absorption requirement is 50 ppm/cm to operate at cryogenic temperature with high power laser

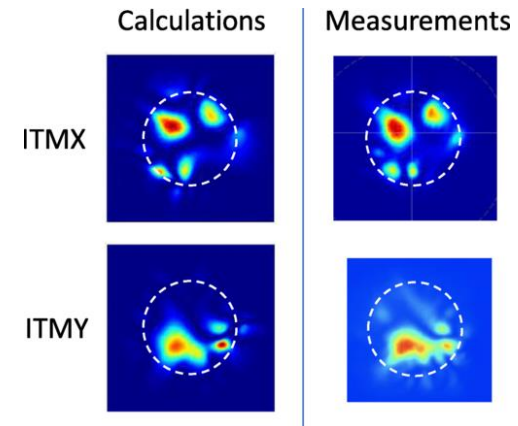


Current ITMs birefringence from TWE measurements

- Absorption and optical homogeneity requirements met [1]
- No direct birefringence measurement but TWE measured with different roll angles of the substrates
- These TWE measurements allowed to reconstruct the substrates birefringence [2]
- Finesse simulations allows to reconstruct p- and s-polarizations inside KAGRA interferometer



Reconstructed birefringence



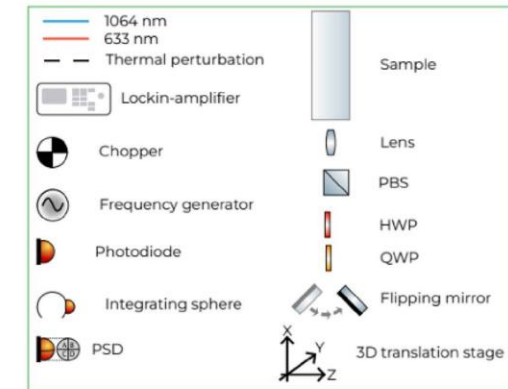
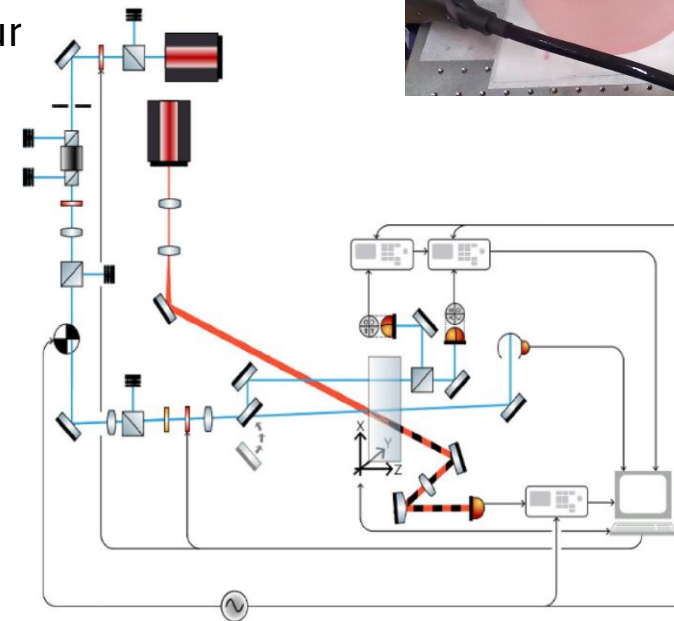
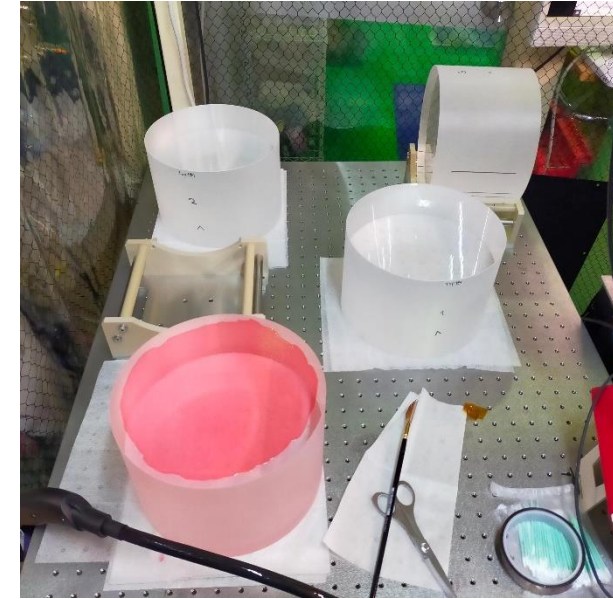
Simulated and measured p-polarized beam in single bounce

[1] :[Characterization of Core Optics in Gravitational-Wave Detectors: Case Study of KAGRA Sapphire Mirrors](#)

[2] : [Characterization of birefringence inhomogeneity of KAGRA sapphire mirrors from transmitted wavefront error measurements](#)

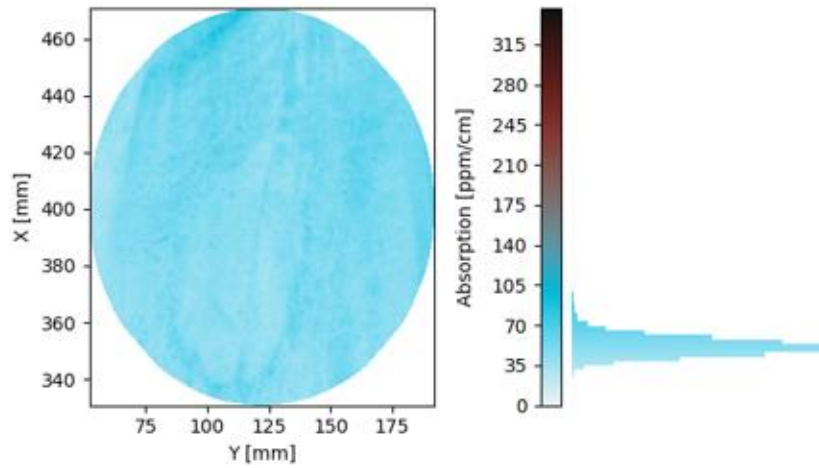
New ITMs

- Grown by AZTEC
- Growth along a-axis
- 2 out of 5 substrates at the absorption requirements
- PCI setup modified into a linear polariscope to measure birefringence [3]
- Ears flats polishing + rough polishing completed
- Currently in fine polishing up to ~ Fall 2025

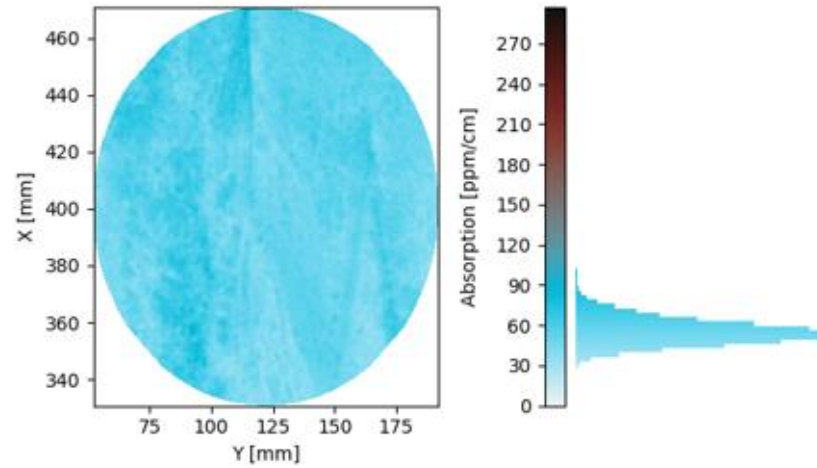


[3] : [Correlation between birefringence and absorption mapping in large-size Sapphire substrates for gravitational-wave interferometry](#)

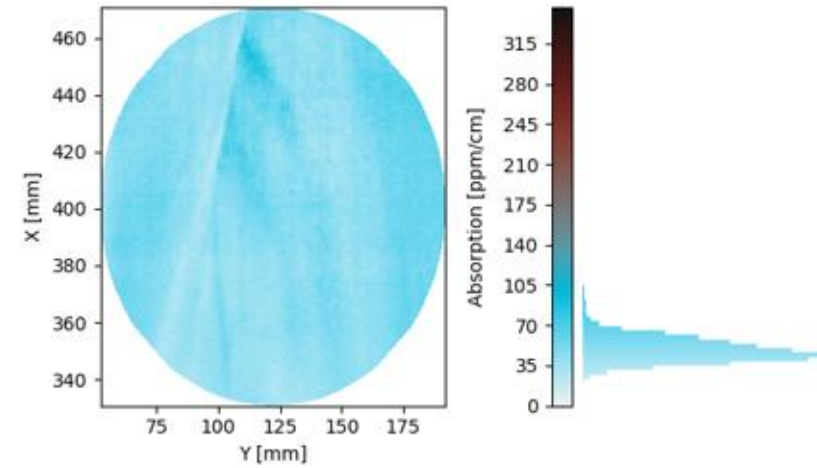
New ITMs absorption example



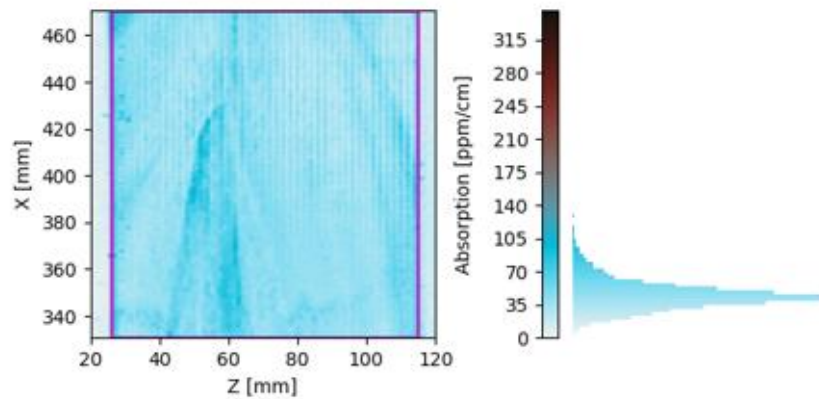
Mean absorption : (46.8 ± 7.54) ppm/cm
at Z = 36.05mm



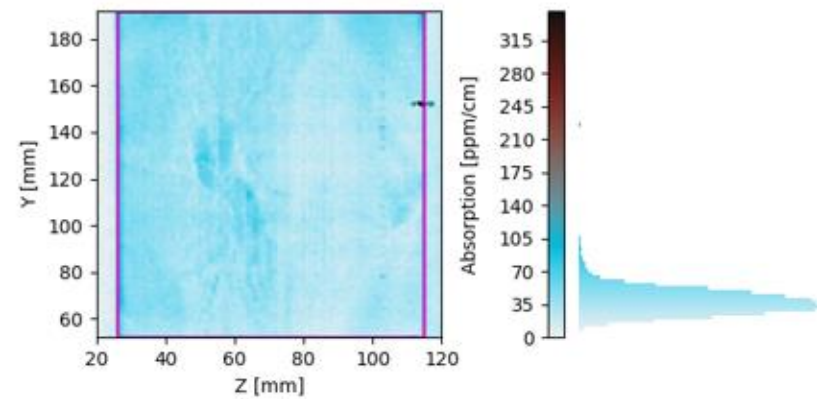
Mean absorption : (50.1 ± 8.46) ppm/cm
at Z = 71.075mm



Mean absorption : (43.7 ± 9.11) ppm/cm
at Z = 104.65mm

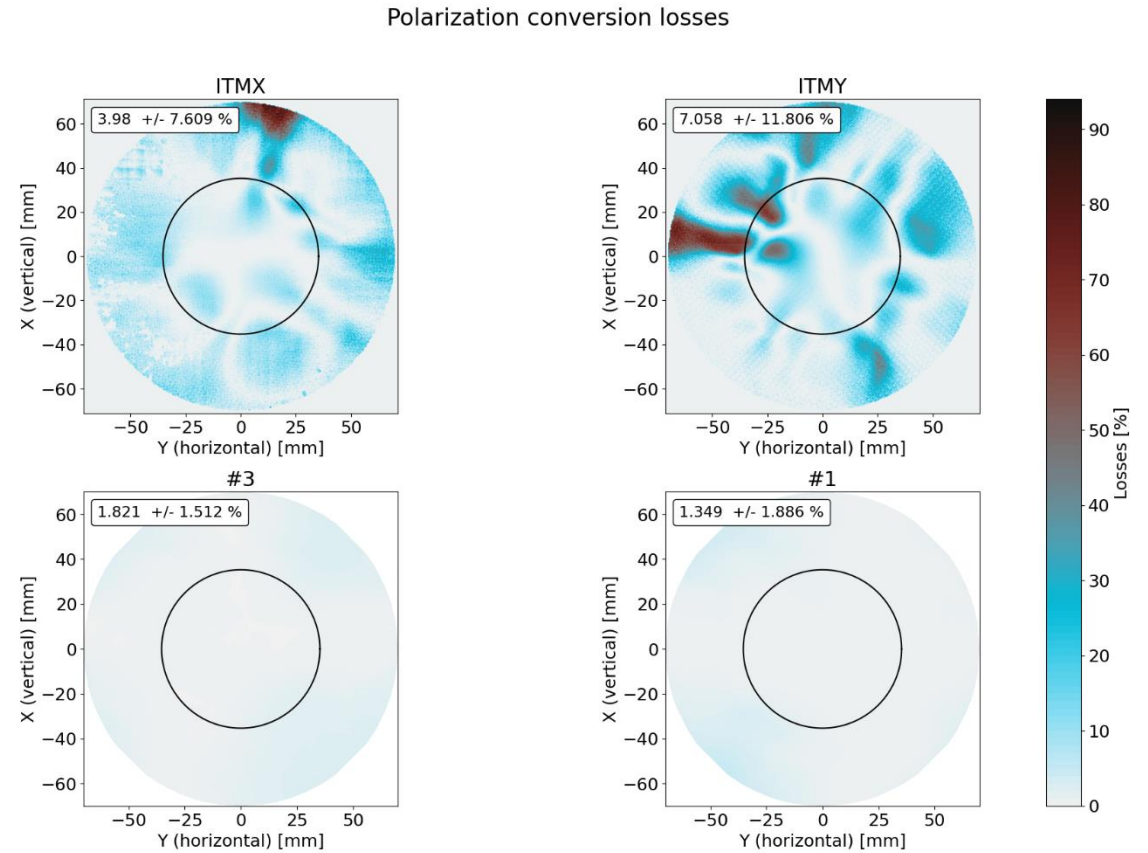
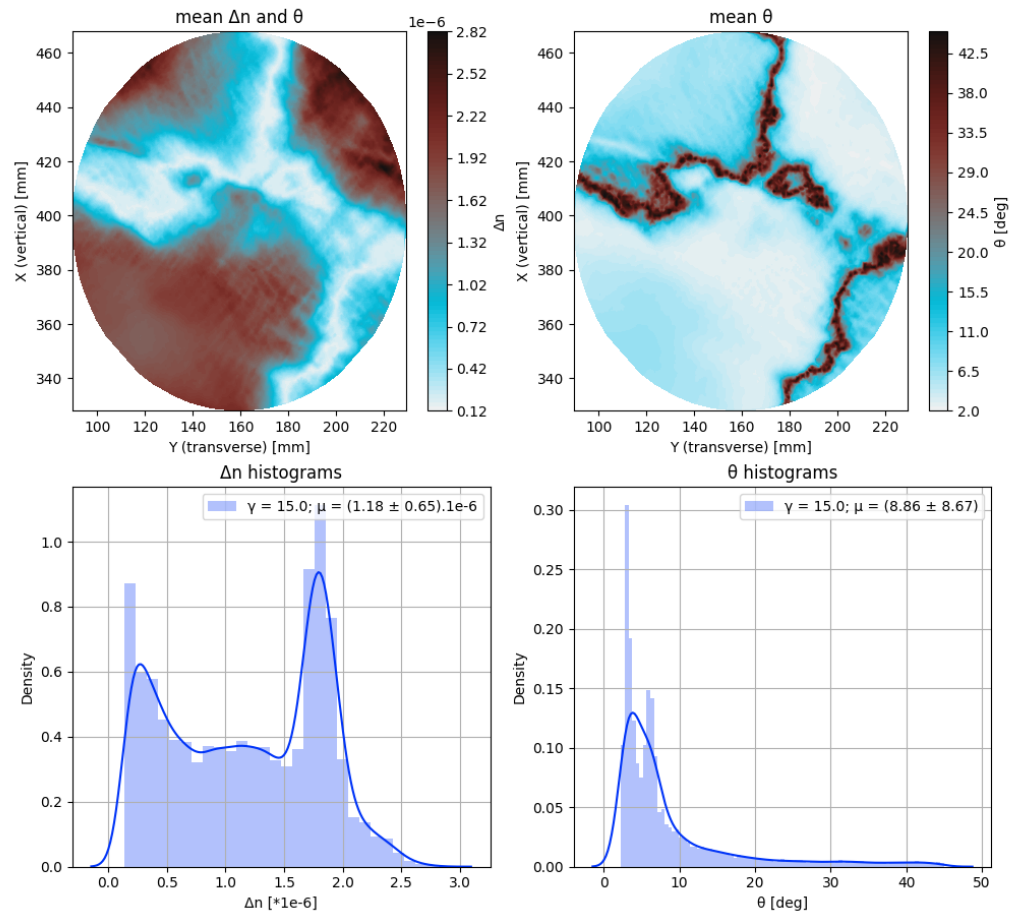


Mean absorption : (40.1 ± 13.49) ppm/cm



Mean absorption : (34.2 ± 12.97) ppm/cm

New ITMs birefringence example

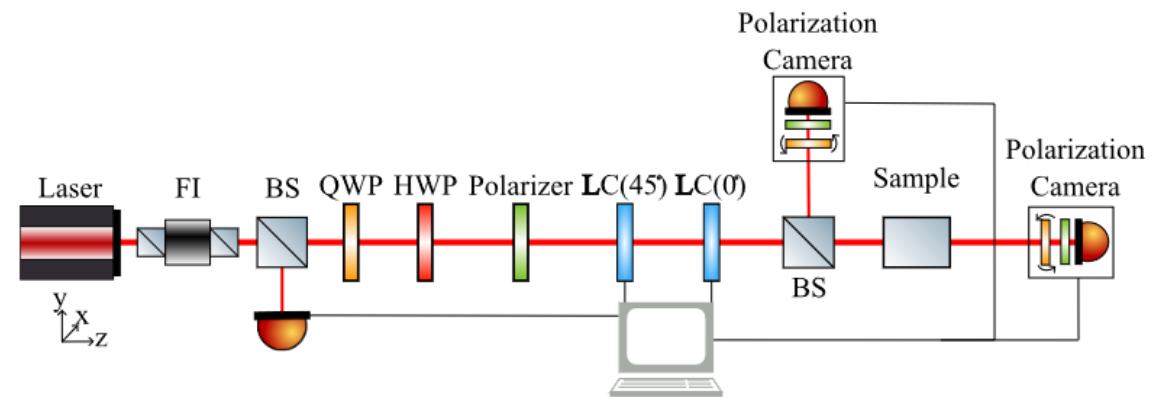
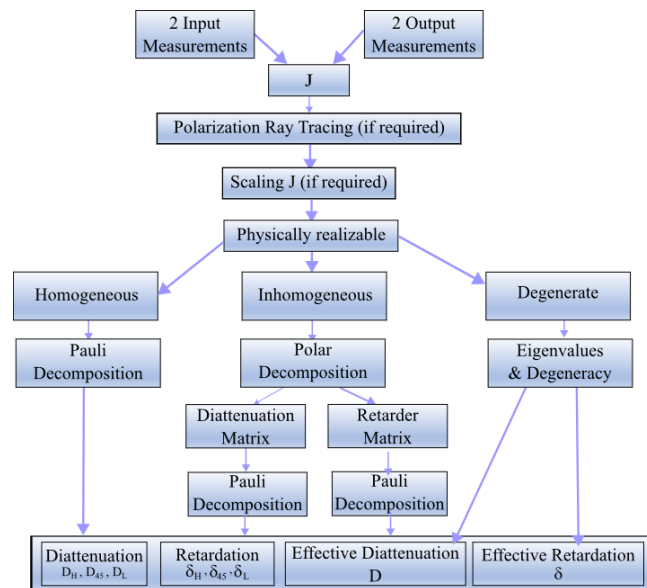


Sapphire growth

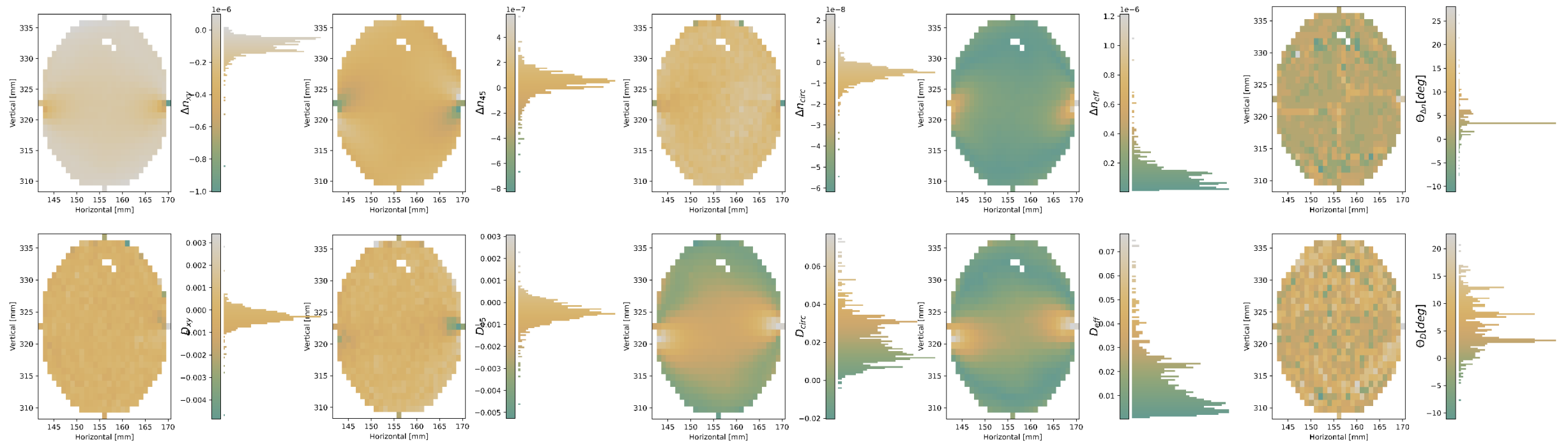
- Shinkosha
 - Sold their growth furnace to another company.
 - No characterization yet of these new substrates
- AZTEC
 - Previous responsible for sapphire growth created its own start-up (currently preparing for growth)
 - KASI provided 30mm and 60mm diameters substrates from AZTEC
- iLM/LMA
 - See Jerome Degallaix talk
 - Characterization of 30mm diameter samples on-going

New birefringence measurement capability

- Measure the Jones matrix of samples in transmission or reflection
- Reconstruct retardation and diattenuation along different axis for realistic Jones matrices
 - Paper in preparation
- Tested in 1D for transmissive retarder/diattenuator + in reflection
- Modified PCI for this measurement compatibility



New AZTEC samples birefringence

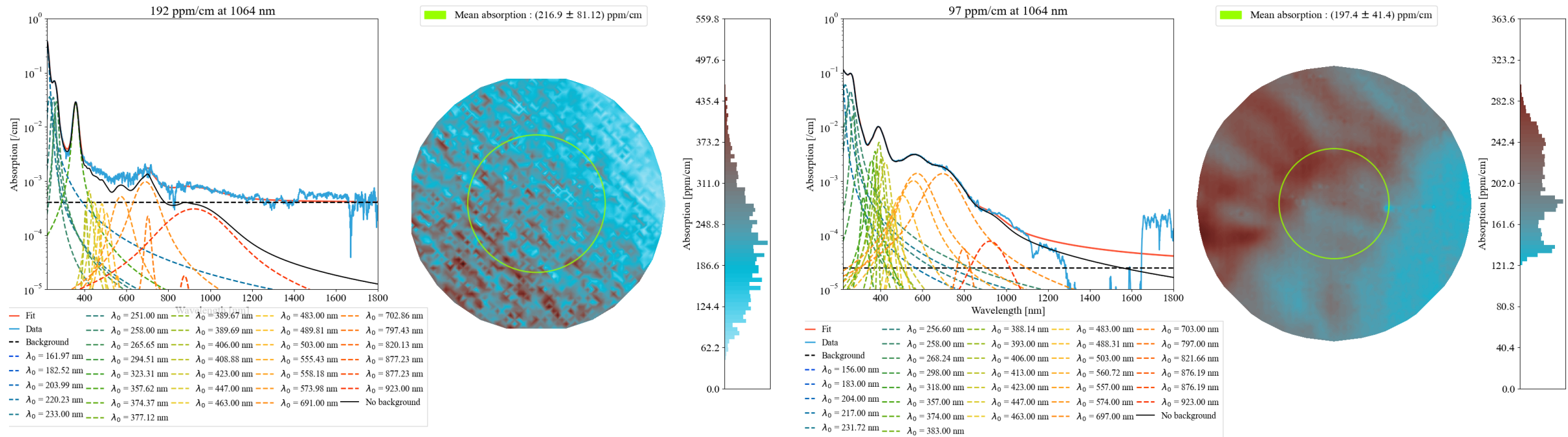


- Can measure retardation/diattenuation of x/y, +/-45 /left/right circular polarization and associated axis location
- Currently measurement limited by stress-induced birefringence from a mounting screw (mid height and right side)
- Except this, birefringence seems to be at or below 10^{-7}
- 3d printed a `stress-free` holder and measurements in December

Spectroscopy

- Measured transmission spectrum of several sapphire samples from 220 to 2600 nm with unpolarized light
- Fit from impurities absorption [4,5,6]
- Compare result with PCI absorption measurement at 1064 nm
- Currently upgrading the setup with a broadband polarizer

[4] : [Characterization of absorption bands in Ti:sapphire crystals](#)
 [5] : [X-ray induced absorption of high-purity sapphire and investigation of the origin of the residual absorption at 1064 nm](#)
 [6] : [Enabling cryogenic gravitational wave detectors: growth of sapphire crystals with record low absorption in the near infrared](#)



KAGRA future test-masses

- Currently discussion on-going within KAGRA collaboration for future configuration of the detector
 - One possibility is to use 40 kg substrates or to use different dimensions
- Plan to measure for all samples absorption spectrum, absorption at 1064nm, retardation and diattenuation
 - Upgrading several characterization capabilities
 - Looking for possible correlations between these properties