IBIC 2015 International Beam Instrumentation Conference
13-17 SEPTEMBER 2015 MCEC MELBOURNE
TUB072
15 Sept 2015

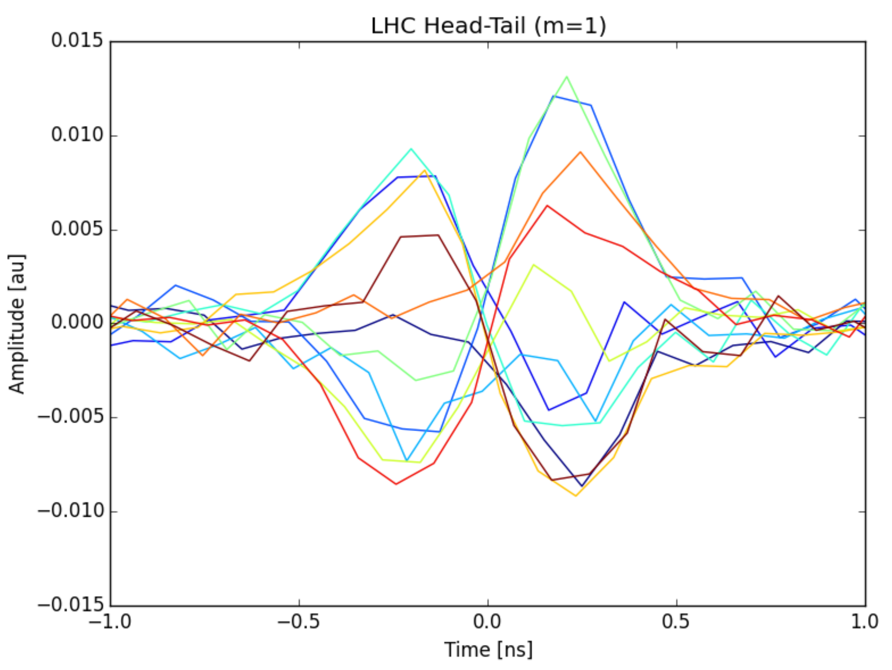
HIGH FREQUENCY ELECTRO-OPTIC BEAM POSITION MONITORS FOR INTRA-BUNCH DIAGNOSTICS AT THE LHC

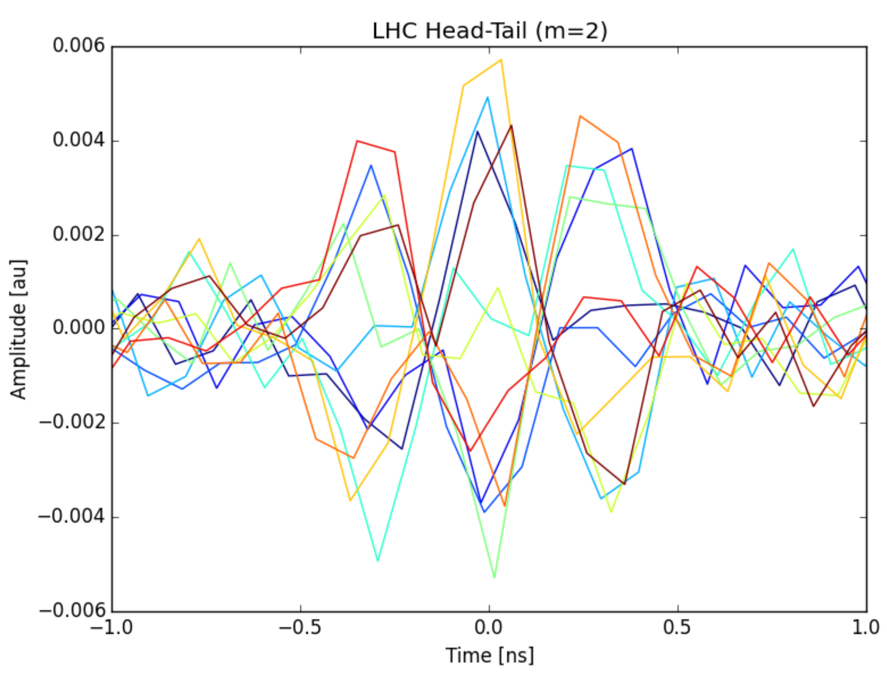
S.M.Gibson[(1*)], A.Arteche [(1)], G.Boorman[(1)], A.Bosco[(1)], P. Y. Darmedru[(2)], T. Lefevre[(2)], T. Levens[(2)]

Motivation

(1) (2)

At the HL-LHC, proton bunches will be rotated by crab-cavities close to the interaction regions to maximize the luminosity. A method to rapidly monitor the transverse position of particles within each 1 ns bunch is required. A novel, compact beam diagnostic to measure the ***bunch rotation*** is under development, based on electro-optic crystals, which have sufficient time resolution (< 50ps) to ***monitor intra-bunch perturbations***.

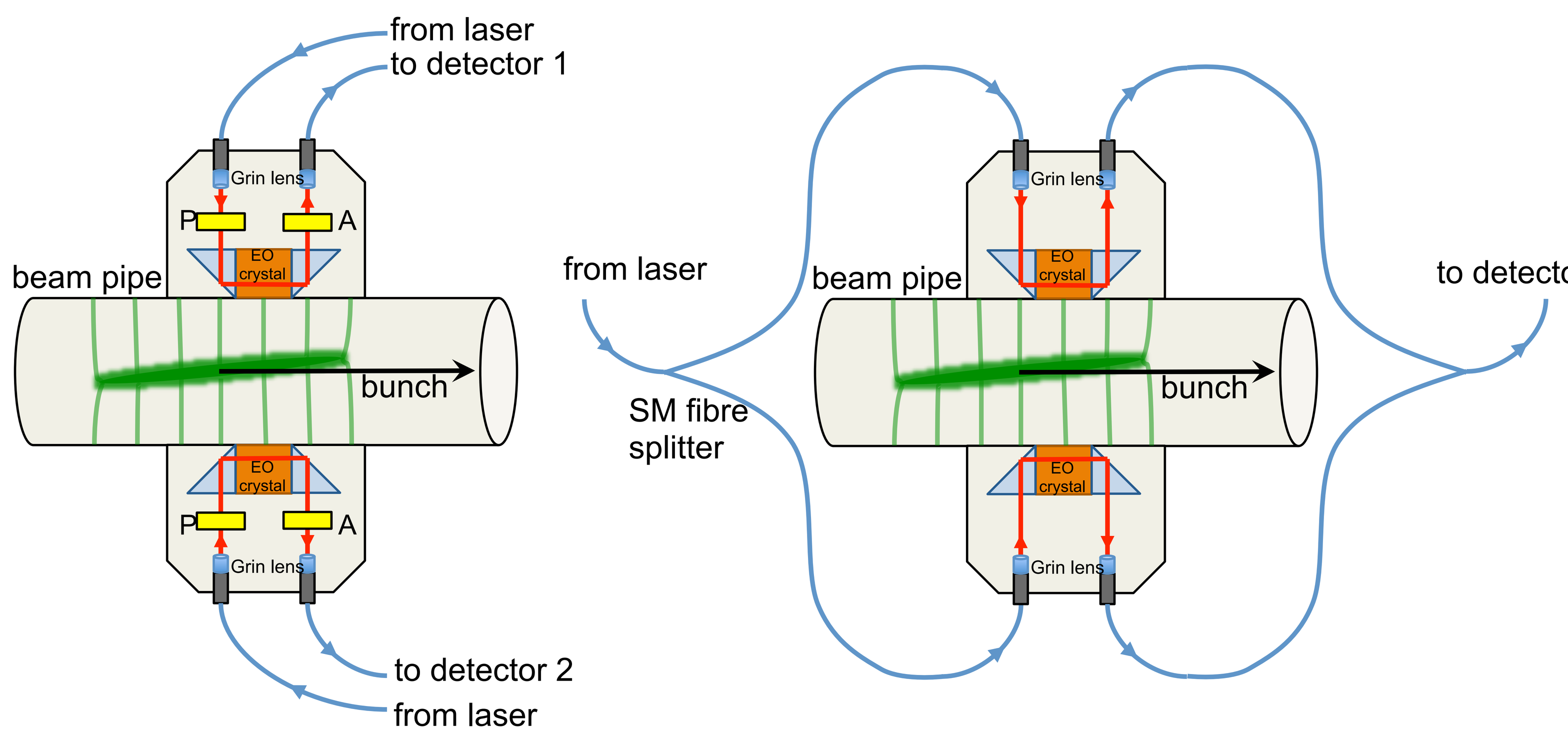




A high-frequency monitor is also necessary to detect ***intra-bunch instabilities*** on a turn by turn basis. The present head-tail monitor at the CERN SPS is based on stripline BPMs and a fast sampling oscilloscope. Recent measurements reveal the low order modes as shown. However the HT monitor only offers a bandwidth up to few GHz limited by the pick- up, the cables and the acquisition system. Electro-optic crystals offer response times in the picosecond range.

A collaboration between CERN BI and Royal Holloway University of London will develop EO-BPMs for the CERN SPS and LHC.

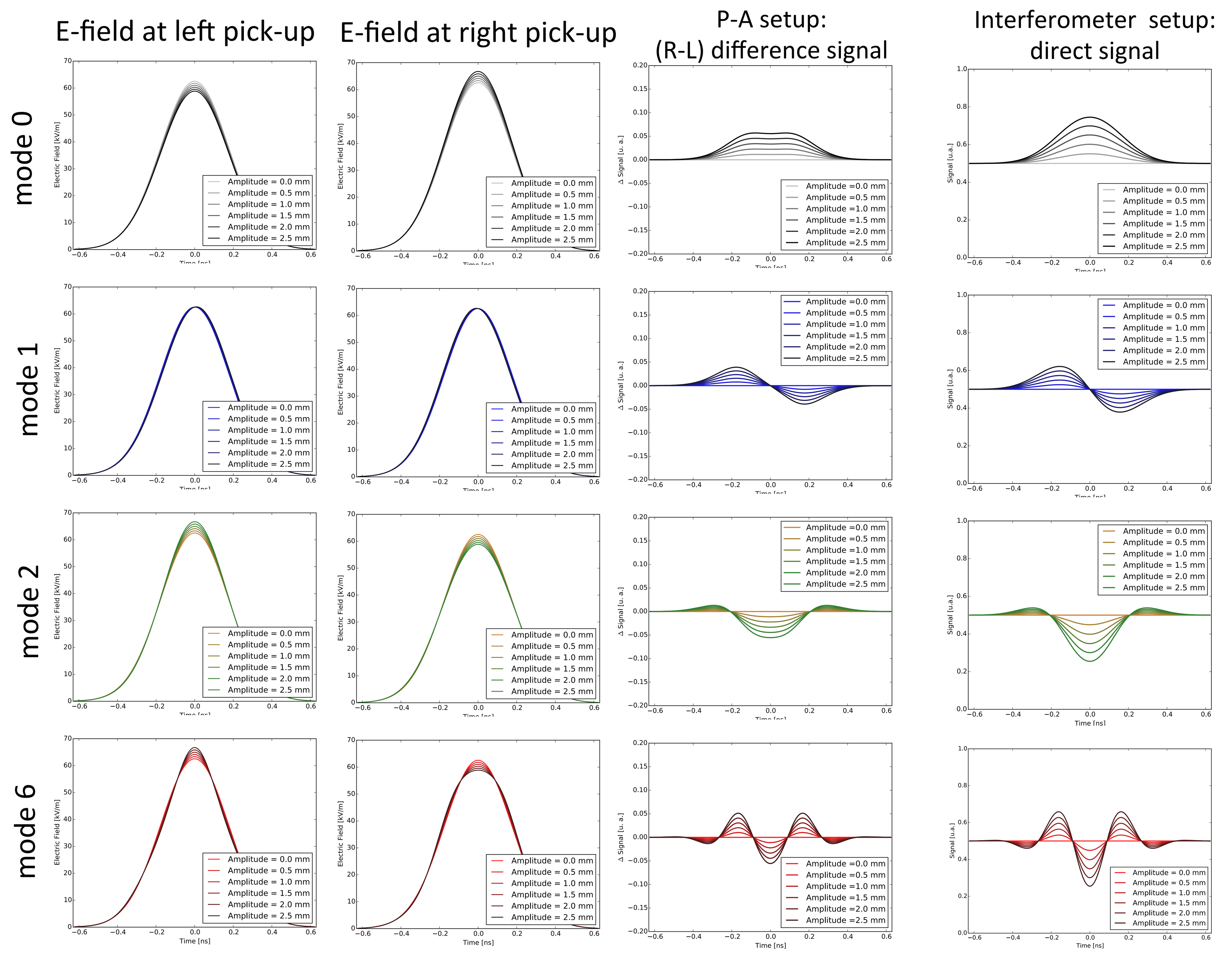
Electro-Optic Beam Position Monitor Concept



An EO-BPM is essentially a conventional button-BPM in which the pick-ups have been replaced with electro-optic crystals, whose birefringence is modified by the electric field of the passing charged particle bunch. The change of birefringence depends on the electric field which itself depends on the bunch position, and can be measured using polarized laser beams (left). In the proposed interferometric layout (right), coherent light is exploited to optically suppress the common mode signal, such that the detector directly measures the difference signal between the two pick-ups.

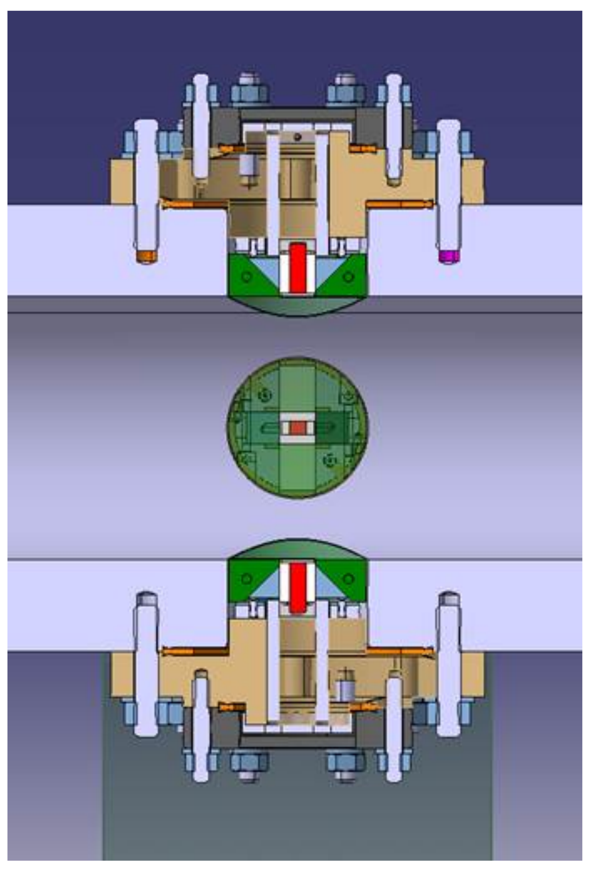
Simulated signals for LHC bunch parameters

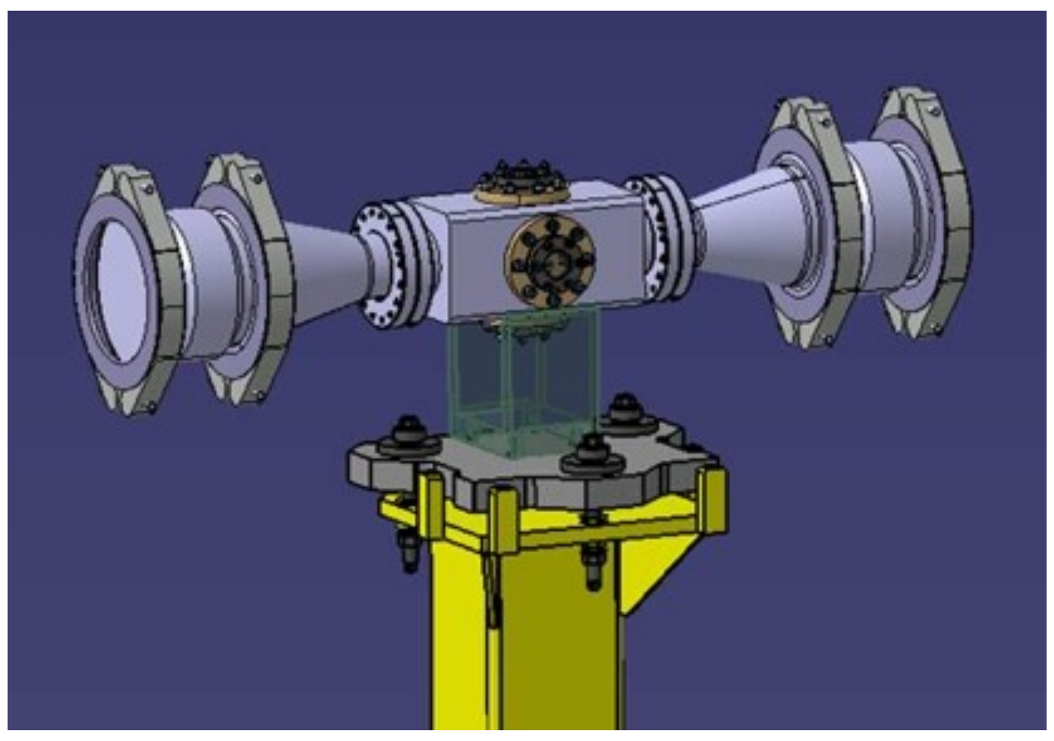
A model has been developed to study the optical response of the crystal to a perturbed relativistic SPS/LHC bunch, 4σ = 1ns length.

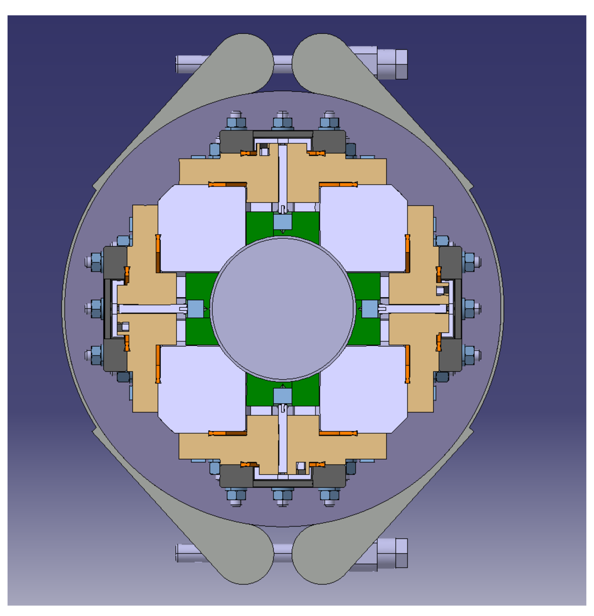


Design of a prototype EO-BPM for the CERN SPS

A beam test of the EO-BPM is planned by installing a prototype in the CERN SPS, to monitor bunch instabilities, with space reserved close to the existing HT-monitor for checks. A taper bring the SPS aperture to the 80 mm diameter, to test the pick-ups at a radius compatible with the LHC. The two conceptual configurations above, will be tested in orthogonal planes.







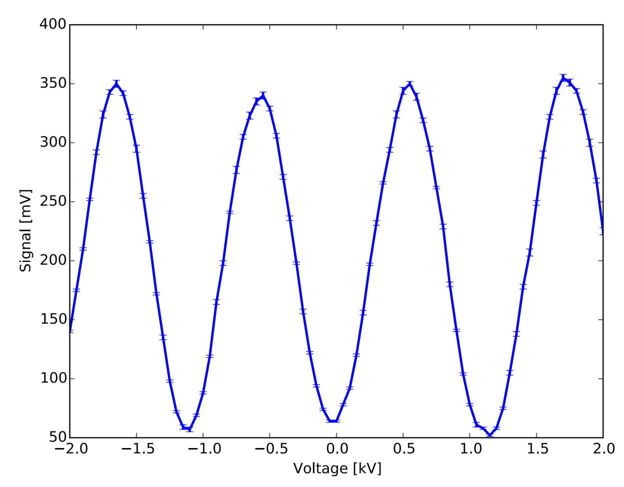
Electro Optical crystal characterisation

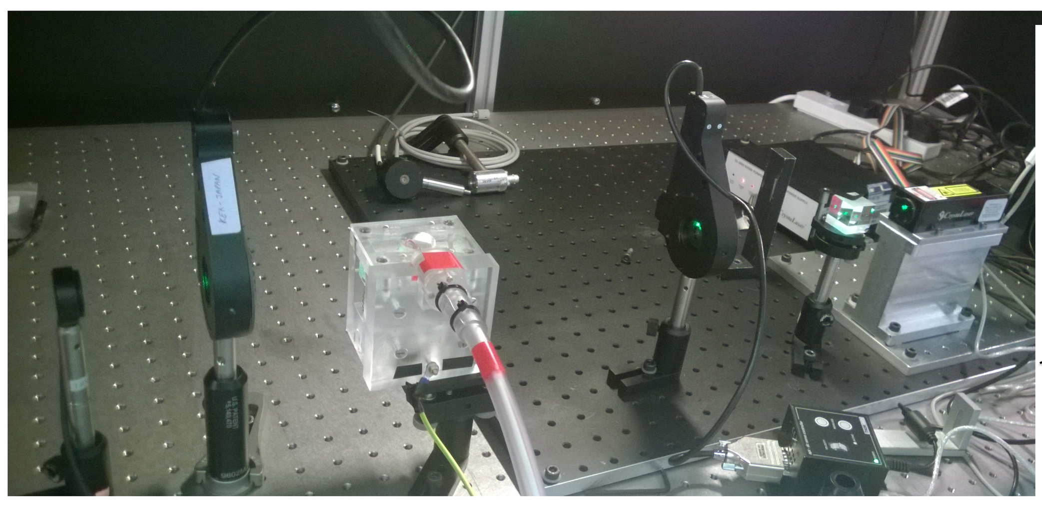
$LiNiO_3$ and $LiTaO_3$ crystals have been characterized with a high voltage modulator and optical test stand at Royal Holloway.

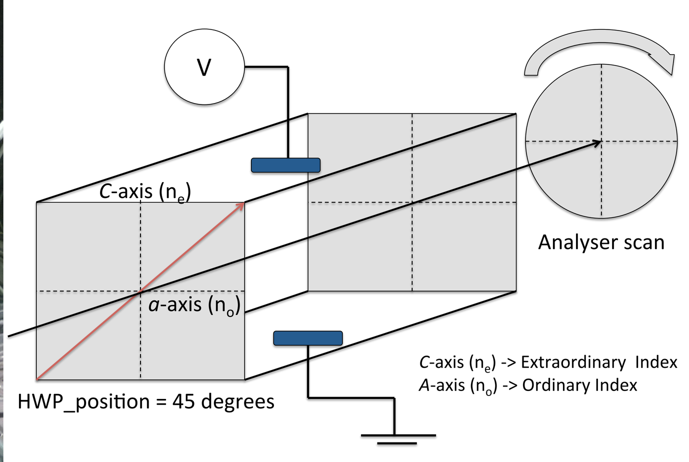
- HV is applied across a z-cut crystal, with light propagating in the x-direction.
- Polarizer at 45 degree and analyzer at 135 degrees.
- The voltage induces a rotation in the polarization axis of light emerging from the crystal.
- The half wave voltage is measured:

$$V_\pi = \frac{\lambda}{r_{33}n_e^3 - r_{13}n_0^3}\frac{d}{L}$$

- The measurement agrees well with the predictions from the crystal parameters.







* stephen.gibson@rhul.ac.uk
(1) John Adams Institute at Royal Holloway, University of London, Egham, Surrey TW20 0EX, UK
(2) CERN, Beam Instrumentation Group.

Acknowledgement: We thank Ralph Steinhagen, Rhodri Jones, Steve Jamison, David Walsh, Laurie Nevay, Alexey Lyapin and Stewart Boogert for helpful discussions.