This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under GA No 101004730.

I.FAST WP10.7

Development of Electro-optical Waveguide Sensors

I.FAST kick-off meeting, May 4th 2021

Stephen Gibson, Royal Holloway University of London

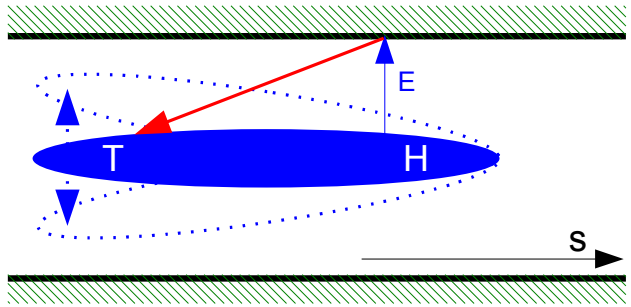
John Adams Institute for Accelerator Science

Task objectives

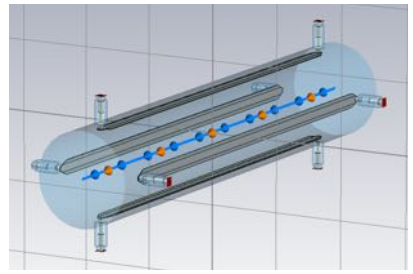
- **Task 10.7: Development of electro-optical waveguide sensors as beam electric field sensors.** M1 – M24 by RHUL & CERN + industry.
- Develop **novel electric-field sensors** based on electro-optic waveguides to address new challenges in fast time response (<50ps) beam instrumentation.
- **Demonstrate the capability** to optically measure the intra-bunch transverse displacement of a passing relativistic bunch, with a bandwidth that is beyond state-of-the-art.

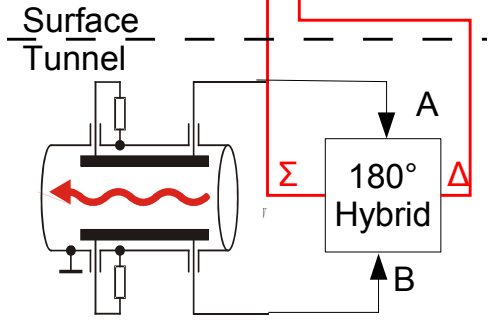
How to make beam **I**nstrumentation **FAST**er?

- ***Challenge of rapid diagnostics***
  - Beam instrumentation at current and future particle accelerators would **benefit from an improved time response** in multiple areas:
    - Bunch arrival time/ ToF; crabbed bunch rotation; temporal longitudinal profiles; measuring rapid, intra-bunch transverse instabilities…
  - **Bandwidth** of conventional diagnostics is typically **limited** to a few GHz by the pick-ups, cables and acquisition system.
- ***A new technology is needed***
  - replace capacitive pick-ups with fast electro-optic crystals
  - replace electric cables by optical-fibre readout



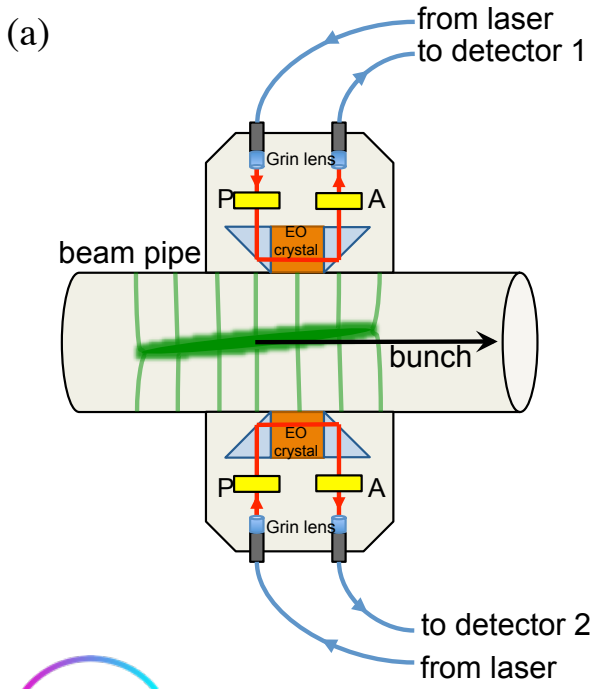
Standard approach: stripline BPM



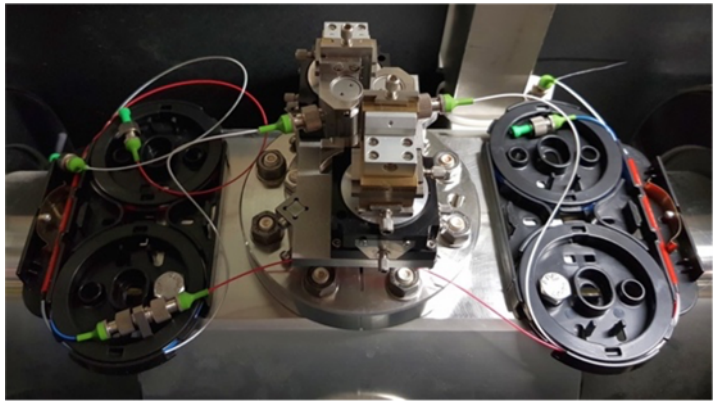


Electro-optic BPM

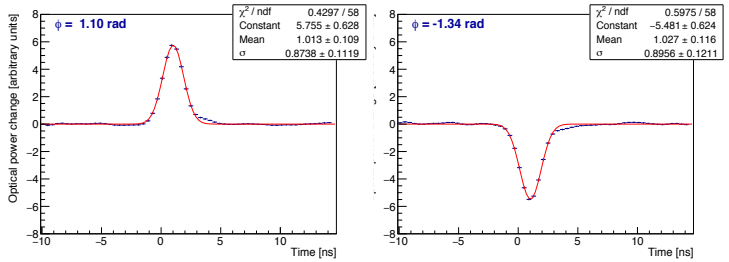
- ***Basic principle:***
  - Monitor the polarisation of light in birefringent crystals in response to the electric-field of a passing bunch



- *Free-space crystal prototype:*
  - Electro-optic detection of proton bunch shown in earlier studies with an in-vacuum, ***free-space EO crystal prototype***



Optical response to SPS bunch – IPAC18:



- **I.FAST Task 10.7 focuses on developing miniaturised e-field sensors based on *electro-optic waveguides***

Partners fabrication & test facilities

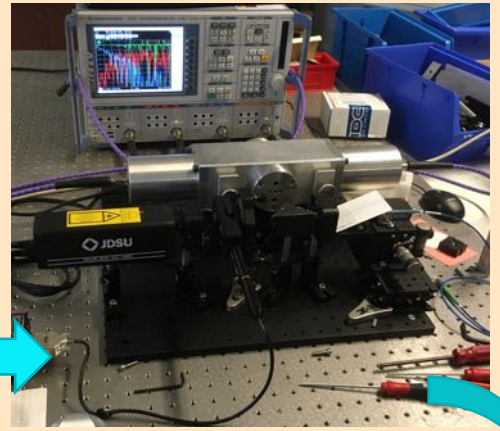
- **Pickup development and bench tests at RHUL**

ROYAL HOLLOWAY UNIVERSITY OF LONDON

Waveguide fabrication in photonics industry

Inspection in new nanofabrication clean-room facility at RHUL

Precision manufacture & waveguide integration



Bench tests on RF coaxial line / laser labs

- **Beam tests of waveguides at CERN**

In collaboration with CERN BI, T. Lefevre et al

CERN

HiRadMat
High-Radiation to Materials

Beam test of waveguide signal

clear

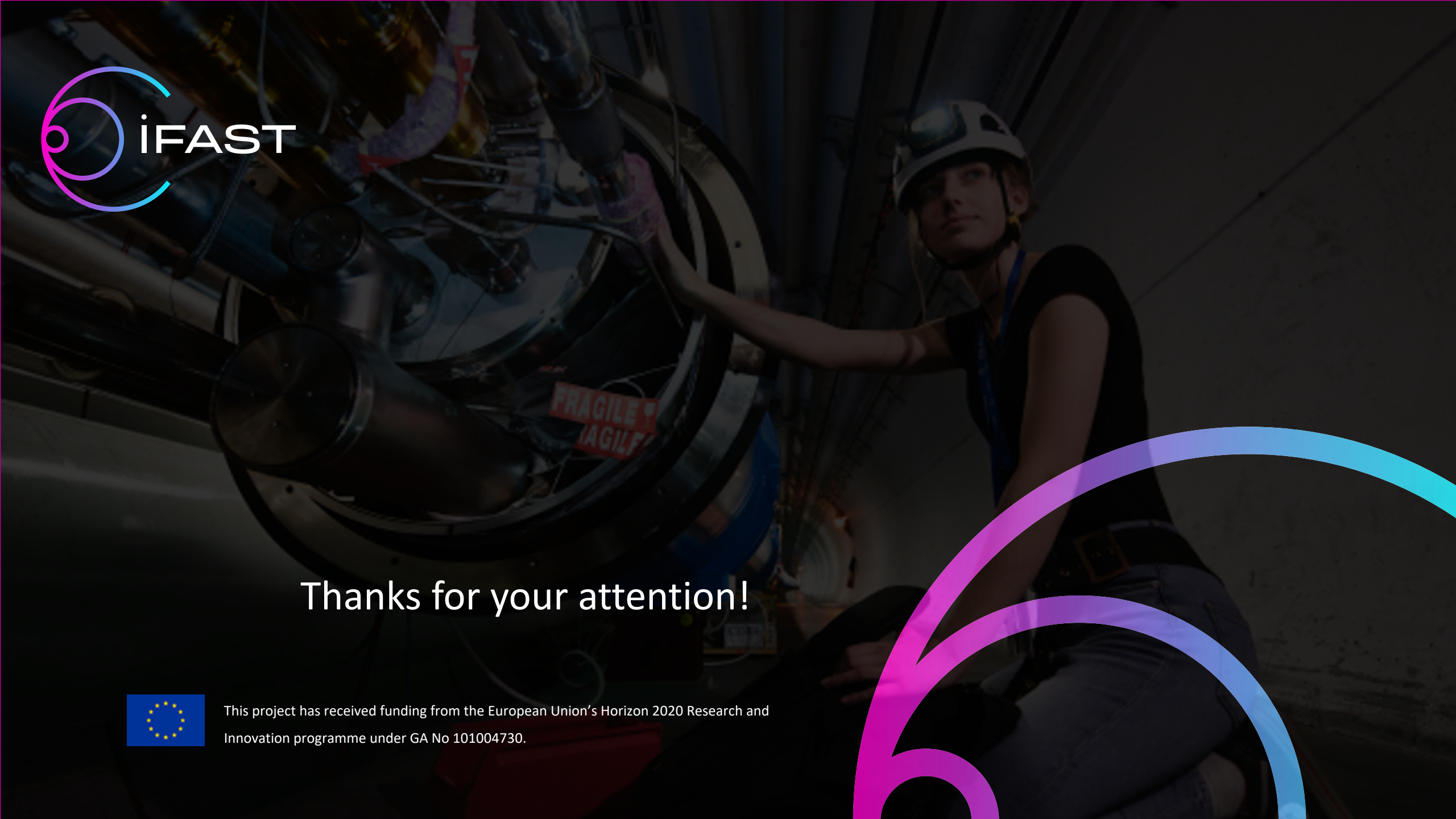
Beam test of waveguide bandwidth

iFAST

Task WP10.7: sub-activities

1. ***Waveguide design and optimisation***
   - Electromagnetic simulation of waveguide response.
   - Optimisation of design in collaboration with photonics industry.
2. ***Development and manufacture***
   - Fabrication in photonics industry of fibre-coupled EO waveguides.
   - Manufacture and integration into EO pick-ups in RHUL clean rooms.
3. ***Test and validation***
   - Bench tests of waveguide pick-ups at RHUL & design optimisation.
   - Beam tests at CERN facilities: HiRadMat & CLEAR.

➢ **Deliverable 10.6: Electro-optic performance report** M24
Final report on the performance of the electro-optic pick-up prototype with beam



Thanks for your attention!

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under GA No 101004730.