

# Industry Projects and Applications

Phillip Tait

STFC Innovation Partnership Fellow at Oxford

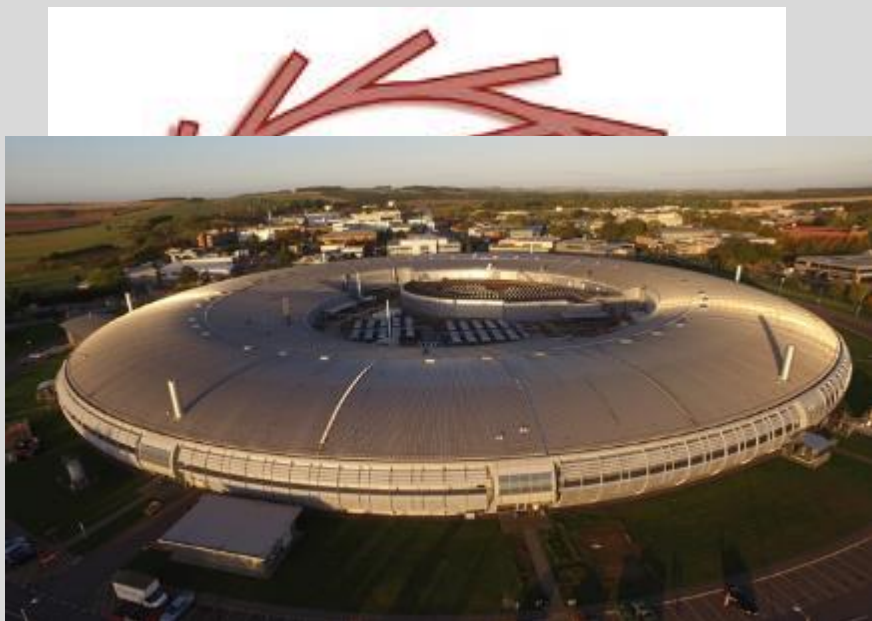
7<sup>th</sup> March 2019

## Summary of some of the industry projects

1. Ultra High Flux (UHF) compact X-ray source
2. Laser based synchrotron sources
3. Cavity based BPM
4. FONT with Industry
5. Precision Metrology
6. Low Cost Medical LINACs

## 1. Ultra high flux (UHF) compact x-ray sources (Ivan Konoplev)

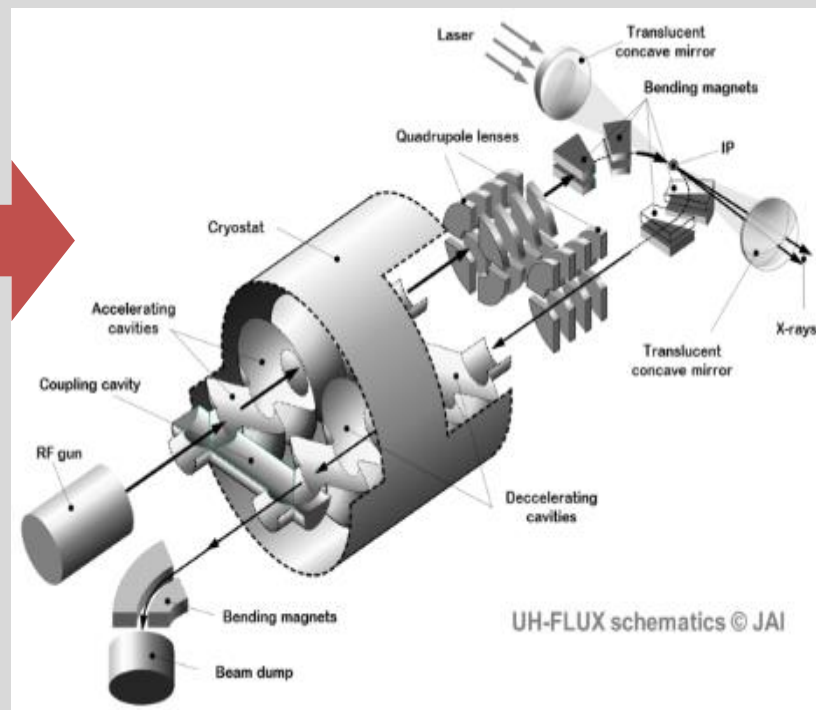
## Very large current designs



Beamline

100+ metre

## Compact Oxford



5 metre

# Industry Projects and Applications

- Shakespeare Engineering & Oxford Physics mechanical workshop **manufacture** asymmetric dual RF Cavity prototypes in AL & Cu
- JAI at Oxford and RHUL have been RF test these prototypes
- Aluminium prototype successfully tested at Oxford
- UCSF (University Challenge Seed Fund) and OIF (Oxford Innovation Fund) gave financial support (£120k)
- OSI (Oxford Science Innovation = venture capital) provided industry contacts



## X-ray Application:

- Non-destructive sources and material/medical diagnostics research market
- £332 billion Semiconductor Industry: \$7 billion lithography market
- Long term - production of medical isotopes by photo fission: The global radioisotope market - \$8 billion

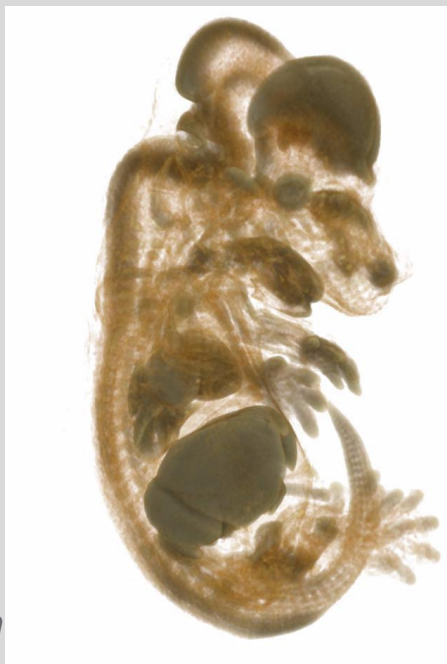
## THz Application

- Cargo Screening: World Market for Explosives, Weapons & Contraband Detection Equipment (EWC) estimated at \$2.1 billion
- Replacing X-ray scanners: The global security screening market estimated at \$9.10 billion
- Imaging of coatings, composites, drug formulation

## 2. Laser based synchrotron sources (Lead Dan Symes)

**Aim: Use laser driven sources to provide industrial imaging capability that cannot be achieved with current commercial technology.**

1mm



14.5 day mouse embryo  $\mu$ CT scan

**10 - 50 keV laser-betatron source with sub-micron source size**

**Development of high resolution, phase enhanced imaging for healthcare applications**

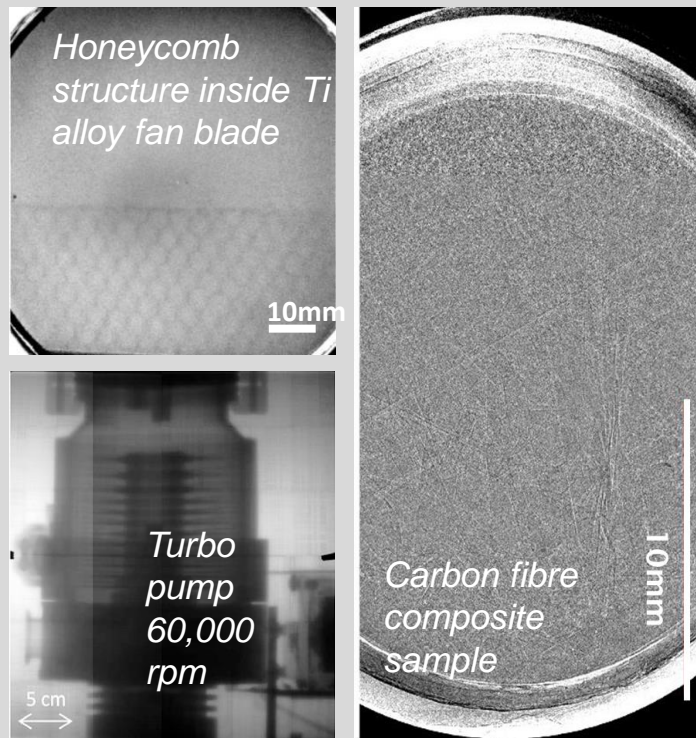
Collaborating with MRC Harwell to conduct  $\mu$ CT for phenotyping.

Working with Imperial College NHS Trust to demonstrate phase enhanced imaging of soft tissues.

**Laser-based instruments offer synchrotron-style capability in laboratory-scale environments.**



## Engaging with industrial partners to explore applications in advanced manufacturing



Proof-of-principle experiments with HVM Catapult, DSTL, Rolls Royce and other companies.

Demonstrated capabilities for non-destructive evaluation

- Phase imaging
- MeV radiography
- Dynamic imaging

**Directional, small source, tuneable x-ray sources 50 keV – multi-MeV**

**CATAPULT**  
High Value Manufacturing

 **Rolls-Royce**

 **Science & Technology  
Facilities Council**

**UK Research  
and Innovation**

## 3. Cavity based BPM (Alexey Lyapin)

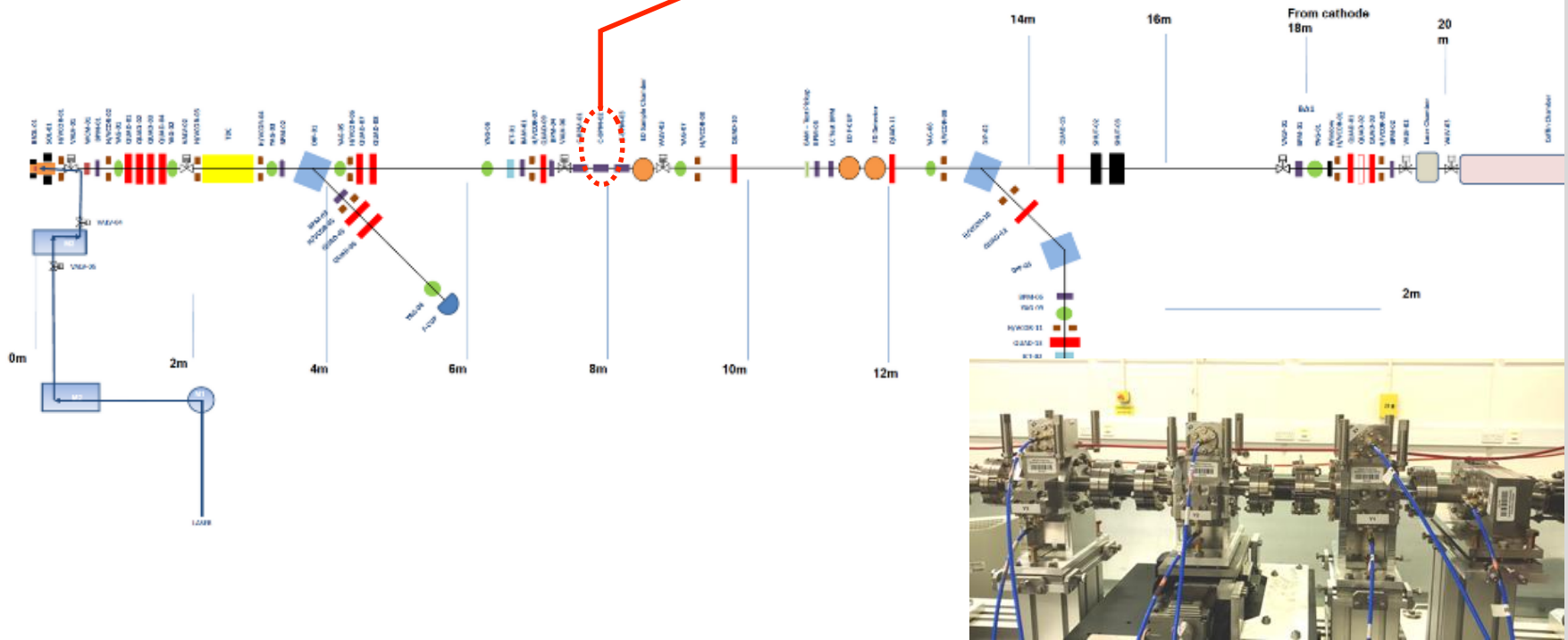
## Aim

- Industrialise cavity BPMs, developed for ILC, in partnership with FMB-Oxford,
- Develop full system that can be easy to manufacture and commercialised
- Beam tests at VELA facility (Daresbury)
- Supported by STFC IPS grant with FMB

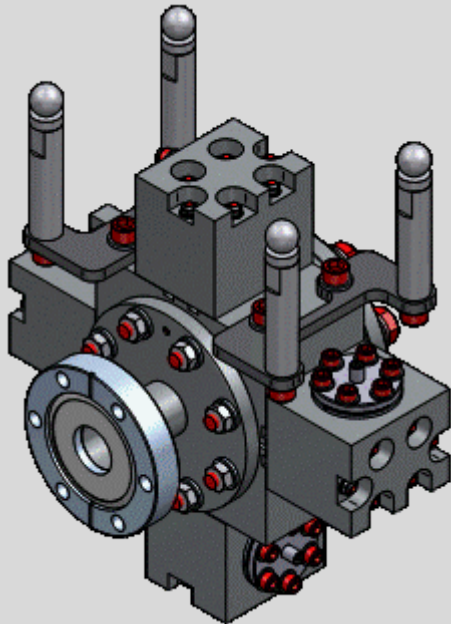
## C-BPM at VELA (Daresbury)

cavity BPM on  
motion stage

VELA Schematic June 2015



- Cavities industrialised and manufactured by FMB-Oxford



## Cavity Design

- 6.5 GHz cavities, aperture up to 20 mm
- Proven common mode rejection method
- Weld/braze-free assembly for cost reduction and reparability
- UHV compatible
- Optimised tolerances – to avoid frequency tuning and reduce cost



## Current Status

- 2 reference cavities manufactured and tested, one installed in VELA
- 3 position cavities manufactured, RF parameters ok, variation from cavity to cavity – excellent, vacuum tested, now to be aligned and installed
- Preparations for vacuum installation – in progress
- RF modules tested as prototypes, now are being replicated and packaged
- Tests at VELA being carried out

## 4. FONT with Industry (Phil Burrows)

## Aim: Commercialise fast RF amplifiers and beam diagnostics

We have won 4 industrial STFC CASE studentship awards :

- Advanced RF devices (TMD Technologies) - *Christine Clarke*
- RF devices for particle accelerators (TMD Technologies) - *Neven Blaskovic*
- Accelerator beam diagnostics (FMB Oxford) - *Talitha Bromwich*
- Radio frequency amplifiers (TMD Technologies) - *Rebecca Ramjiawan*
  
- The high-power amplifier developed with TMD would not have been possible without this 2-way dialogue
  
- Following collaboration with JAI, TMD Technologies has won a large contract to fabricate RF accelerating cavities for CLIC. This enables TMD to develop capability for designing and manufacturing products for additional markets in scientific, medical and communications systems.



## 5. Precision Metrology (Armin Reichhold)

Aim: Commercially produce interferometric distance sensors  
- A technology from ILC to industry applications

- FSI = Frequency Scanning Interferometry
- Up to 100 simultaneous absolute distance scans
- Range 0.1m to 100m
  
- Scan parameters
  - position resolution  $< \pm 0.1 \mu\text{m}$
  - time resolution 2.77 MHz
  - repetition rate 0.1 to 10 Hz
  - dead time  $> 0.1 \text{ s}$
  - Analysis latency  $> 1 \text{ s}$
- Target motion  $< 19 \text{ mm/s}$
- Vacuum & cryogenic environments
- One fibre per channel



## Commercialisation So Far

- Base-technology Patent (dFSI) applied 2011, granted 2015
- Four licenses to Etalon AG for patent and know how (2012)
- 1<sup>st</sup> generation sales of Etalon's "Absolute Multiline™" start in 2013
- 2<sup>nd</sup> generation ( $\mu$ TCA) orders started 2016
- Sales and orders to date approx. £1.4M
- Orders expected in 2019: £0.5M

### Customers so far inc:

- CERN , SLAC
- GMTO (Giant Magellan Telescope)
- General Electric
- E-ELT

### High probability sales inc:

- Porsche
- UK national satellite test facility
- National Metrology Institute Spain

# What is missing in dFSI ?

- No real time measurement due to latency
- No continuous measurements at full time resolution
- No fast moving targets
- Not useable in fast feedback systems for:
  - machine tools (CNC mills, lathes) and Coordinate Measurement Machines.
  - stabilisation of accelerators, telescopes, space simulators, etc.

## Next step = PaMlr (Phase Modulation Interferometry)

- Full technique expected to give:
  - 1m/s target motion @ 0.1 ms latency, continuous observation
- 3-year IPS project started Feb 2019 (£600k total)
- Etalon AG co-fund
  - 30k€ cash + 3 FTE yrs. in kind)
- VadaTech Ltd. co-fund
  - 0.5 engineering FTE years cash
  - permanent position for engineer afterwards
  - in kind engineering support
- New staff hired - PDRA + senior FPGA engineer

# 6. Low Cost Medical LINACs (Suzie Sheehy and others)

Radiotherapy is used in half of all cancer cases (when available)

- The annual global incidence of cancer is expected to rise from 15 million cases in 2015 to as many as 25 million cases in 2035.
- Of these, it is estimated that 65–70% will occur in low- and middle-income countries (LMICs)
- “There is a shortfall of more than 5000 radiotherapy machines in LMICS, with patients in some countries in Africa and Asia having almost no access to radiation therapy”
- Can we make a medical LINAC that is: cheaper, more robust, easier to maintain, modular, reliable while providing state-of-the-art treatment?

- CERN hosted workshop on: "Design Characteristics of a Novel Linear Accelerator for Challenging Environments"
- Funded projects on:
  1. Study of Accelerator Technology Options – P. McIntosh, DL/STFC
  2. Robust permanent magnet beam delivery systems – S. Sheehy, Oxford/JAI
  3. RF Power Systems and Optimized RF Structures for Electron Beam Acceleration – I. Konoplev, Oxford/JAI
  4. Linear Accelerator Simulations for Stable and Sustainable Operation of Developing Country Radiotherapy Linear Accelerators – S. Boogert, RHUL/JAI
  5. Cloud-based Electronic Infrastructure in Support of Linac-based Radiotherapy in Challenging Environments, A. Aggarwal, KCL/Guys



## Additional News

- STFC have awarded 2019 round of Impact Acceleration Accounts (IAA) approx. £70k
- STFC have announced (this week) Capital Funding available for IPS/FoF grants from May 2019 – details tbc
- STFC have announced (this week) Additional Capital fund for current holders of IPS Grants – details tbc
- JAI sits on the High Powered Radio Frequency Forum – Members inc. TMD, Qinetiq, Home Office, Leonardo, e2v, Elekta, AWE, and ASTeC
  - Members want to work together to influence UK Gov Industrial Strategy Challenge Fund

Thank you

[phillip.tait@physics.ox.ac.uk](mailto:phillip.tait@physics.ox.ac.uk)