CfI Programme 2017-2018 Neil Geddes

Summary: The CFI programme funded 4 short term and 7 longer term projects through 2017-18. In total the 200k investment in responsive mode projects has resulted in £500k direct follow on CFI funding, and improved exploitation of the diamond turning facilities, with targets produced using this technology fielded on lasers around the world. Highlights from the Managed Programmes include:

- Capability to indium bum bond wafers up to 200mm
- Improved modelling of properties of Infra-red Glass waveguides, removing the need for some prototypes.
- Vendor independent IP for 10, 40 and 100 Gb/S Ethernet.
- Experience with pixel and amplifier design in 65nm technology.
- 35x increase in the responsivity of 300GHz THz sensors.
- Successfully record THz emission from all electron bunches on the DLS ring.
- Successful demonstration of infra-red sensitivity of SLS IR devices at high rate (but with low yield)
- £400k FEM-2 orders supplied to customers.

Introduction

Through the 2017-18 financial year, the TD Centre for Instrumentation funded 7 larger multi-year Managed Programmes and 4 smaller Responsive Mode projects. The outputs achieved during the year are summarised. For the managed programmes in particular, in-year achievements may be the result of several years of development. Technical achievements are summarised as well as follow on projects or contracts.

Responsive Mode Projects

Six responsive mode projects were funded in 2016/17:

Miniature coolers for CubeSat applications (£31k) investigated the requirements and feasibility of developing miniature coolers for CubeSat applications. The outputs from this work are included in a paper to be presented at SPIE 2018. The project has expanded to include a bread-boarding activity to develop a low-cost compressor for a brayton-cycle cooler

Fast Plastics for Thermal Neutron Detection (£23.2k) investigated the suitability of a new generation of lithium loaded plastic scintillators for use at the ISIS neutron facility. The emission decay of the plastics is different between neutrons and γ-rays allowing for the γ-ray background to be removed using a technique called pulse shape discrimination. Early analysis of the data shows that the scintillator (EJ-270 measuring 60 mm x 60 mm x 100 mm from Eljen) has much higher rate capabilities than other detectors currently used as point detectors for reflectometers (roughly 50 times higher rate), there was no indication of neutron induced radiation damage following exposure (to MGy levels) on the Emma beamline at ISIS. This difference in n and gamma signals is, however, in the last 10% of the signal and occurs at around 70 ns which will be challenging to achieve. Further

beam tests are scheduled for March 2018. Two papers are planned to be published with Surrey University. A follow on project (£35k) to investigate the pulse shape discrimination was funded for 2018/19.

Ultra-Precision Diamond Turning for Optics and High Power Laser Targets (£20k) supported a single point diamond turning development program to understand the complex surface patterning, using a wide range of metrology facilities. The first simple parts were produced within the first few months of the implementation of the project. Standard flats and optical surfaces can be produced, however the metrology of the parts is a complex challenge. The surface roughness in the small scale can be measured using white light interferometers that are available in the Target Fab group in the CLF. Production of parts has been improved by the purchase of a CAD system to talk to the machine software directly. This has reduced timescales for programming and opened up new geometry possibilities. A laser sintered mirror was machined with a high quality surface and targets produced using this technology have been fielded on lasers around the world.

Hexitec (£90k) combined a number of smaller proposals into a programme to investigate the development of high energy and high rate x-ray detectors. Delays in CZT delivery and availability of LCLS time (now scheduled for April 2018) have delayed this programme. High rate CZT is now delivered and assembled (using most of the allocated funding). Planned tests will be completed in 2018/19 (funded separately). The readout requirements for high rate and high energy systems has led to a new CFI managed programme for front end electronics development.

In total the 164k investment in responsive mode projects has resulted in development of new precision turning capability, confirmation of the radiation hardness of new fast plastic scintillators, 3 publications and follow on CFI funding of £0.5M.

Managed Programmes

In parallel the CFI managed programmes focussed on developing (or sourcing) and sustaining underpinning technological capabilities as well as development of new capabilities.

Advanced Interconnects. This Progamme has now closed. The final year of the programme focused on improving the indium bump bonding finesse and yield and deploying the capability to process 200mm wafers. This technology has been successfully deployed on detectors for PPD and synchrotrons and for bonding GaAs. STFC has received some recognition through its active membership of the UK chapter of the International Microelectronics Assembly and Packaging Society.

Optics. The IG2 (Infra-red glass) waveguide couplers from Heriot-Watt have been fully characterized. The tests on IG2 have provided all the information needed for future waveguide modelling and sample IG2 is no longer considered necessary. Recent results have been published at SPIE [1] and a paper submitted to Optics Express. The work was also presented at a workshop on dispersing elements for astronomy (October 2017, http://www.brera.inaf.it/DispersingElements2017/program.htm). Three new anti-reflection coated

[1] Helen L. Butcher, David G. MacLachlan, David Lee, Robert R. Thomson, Damien Weidmann, "Ultrafast laser-inscribed waveguides in IG2 chalcogenide glass for mid-infrared photonics applications," Proc. SPIE 10535, Integrated Optics: Devices, Materials, and Technologies XXII, 1053514 (23 February 2018) https://doi.org/10.1117/12.2288333

prototypes were manufactured and successfully characterised. As a result of this prototype testing the laser inscription process has been modified slightly to use a higher laser pulse energy. The final mid-infrared grating, for use at in the spectroscopic sensor at RAL Space, has now been delivered to STFC and is under testing at the UK ATC.

DAQ. This programme has now closed. STFC IP for Vendor-independent, scalable: 10, 40 & 100 Gb/s Ethernet has been developed and successfully deployed on SKA prototypes, DLS, Quantum Detectors and E-ELT prototypes. FEM-II hardware development completed and 37 boards have been produced so far (~£400k, funded by customers). Initial test structures for 10Gb/s serial ASIC readout have been developed and will be taken forward in future ASIC developments.

Microelectronics. Test structure for 65nm adaptive gain pre-amplifiers has been submitted for manufacture. Work has continued on a demonstrator ASIC for the adaptive gain pixel. The Pixel control logic has been revisited to add extra programmability as there's more space for logic with the 65nm process. Work on a 10GHz Serialiser and the associated blocks (for fast serial readout for next generation ASICs) has continued with good progress. A design review of the Serialiser and PLL was held in August 2017.

Terahertz Detectors. This programme has now completed having confirmed a 35x increase in the responsivity of 300GHz sensors. Improvements in packaging and assembly process have also reduced the complexity of the devices and increased GaAs device yield to 90%. The produced sensors have been used to successfully record single shot THz emission from all electron bunches on the DLS ring. This work has led to two invited conference talks and a further conference poster.

Sensors. Further tests with large area GaAs sensors have been conducted, producing good line scans showing 600eV FWHM on 250um pixels. This work is being written up for publication (and more tests are scheduled together with the LCLS detectors group). Tests of the SLS IR devices showed several strips which were IR sensitive to the 2.5-8um source. The device was cooled to -40C and -70C. Initial results give good hope of 100kHz operation. However, only 10's of strips worked correctly. Lancaster now have some new devices with different Sb fraction which could be interesting, but there is as yet no confirmed delivery schedule for these.

CMOS MAPS has initiated work on low noise, radiation hard and high spatial resolution pixels. For the latter, discussions with Open University have identified a new process likely to be available through TowerJazz to provide fully depleted pixels (for improved spatial resolution). The first radiation hard structures have been submitted through CERN and are now back for testing. Work on low (sub-electron) noise circuitry is underway based on high conversion gain pixels from TowerJazz. Initial indications are that this circuitry is noisier the faster it runs.