Proposal for new Australian capability in advanced and custom optical device fabrication

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Australia leads the world in many areas of basic optical science, yet has to date been largely unable to translate this to advances in fields where optics is a major enabler in other kinds of fundamental research, to applied research using complete optical systems, or to commercial outcomes. A large part of the issue is the lack of a national capability in optical fabrication that enables end users to get a fully packaged/interfaced device made to their design and meeting their performance specification. Further, this capability needs to provide rapid turnaround at palatable cost, such that evaluation, analysis, design iteration and revised device fabrication are possible in a short time frame. The importance of short cycle times in enabling fast iterative improvement cannot be overstated, and having personally experienced the benefits of this whilst being an executive in a Silicon Valley start-up I can say with complete confidence that such a capability will significantly accelerate Australian research and enhance commercialisation opportunities. The ability to perform fast iterative improvement in optical devices is key to maintaining Australian leadership and competitive advantages in both research and industry and is a major retarding factor in the advancement of Australian science and industry. A national capability in this field enables the development of new product lines in Australia within existing industry and the formation of new "fabless" commercial entities in the field, as the capital and operational costs of such capabilities are otherwise way beyond the scope of venture funding and often even multinational corporations where research for new products is concerned.

Against this background, Australia has over the last 20 years made major investments in infrastructure via ARC, NCRIS, and other government and industry backed funding mechanisms which have actually provided most of the baseline infrastructure needed to supply the capability described above. Additionally much research has been funded on optical fabrication and there are now several research groups in Australia with demonstrated expertise and proven/mature high performance fabrication processes in all the types of fabrication required, a number of these being world leading. The gap that prevents the capability being realised is in funding the existing skilled and experienced personnel so that the dedicated capacity and expertise is available to service to end users be they in academia, government, defence, or industry. Hence it is proposed to leverage the past infrastructure investments and available proven expertise by funding staff not currently supported under NCRIS in a foundry style operation that sits perhaps on top of ANFF as that is the closest fit to the proposed model and a large degree of infrastructure sharing can be accomplished. A large number of non-NCRIS funded tools could then also be brought under the NCRIS umbrella and the capabilities made available in a reliable and responsive manner. A small number of new tools will also be required, the emphasis here being on high specification repeatable fabrication to ensure performance can be "guaranteed" and small volume production runs made when requested.

The capability aims to advance research fields such as Astrophotonics/observational Astrophysics, optical sensing of many kinds for diverse applications, gravity wave research via LIGO, Quantum optical processing, optical metrology and instrumentation, advanced telecommunications, etc, all areas of major Australian strength on the world stage. The capability will also encourage new start-ups and support current nascent start-ups requiring access to such technologies as currently there is a major disincentive to commercialise in optics due to a lack of development and foundry style services (ie like an incubator) in Australia. Venture Capital will also not fund the establishment of such capabilities in start-ups as it is a huge initial cost on top of the normal uncertainty present with a start-up. Established industries in Australia looking to grow into areas requiring such capabilities will benefit also in that the development of new or improved product lines will become faster and much more affordable, not requiring the high costs and time required to source extensive and expensive infrastructure and expertise. The rapid turnaround capability would also enable Australian researchers and industry to shorten design cycles with a closer connection to the fabrication also providing enhanced understanding of pertinent issues and better, faster, lower cost outcomes.

In concrete terms, the capability would revolve around four major streams: specialised “bulk” optics, high performance and custom optical coatings, advanced and hybrid integrated optics, and high stability low loss reliable packaging of all the above elements into a real world useable final device/system. The capability thus bridges the macroscale to the nanoscale, including integrating the two which is essential to a device for practical application.

For the bulk optics technologies, the processes proposed for support are:

- diamond turning for complex aspheric, conic, and atoric structures as mirrors in aluminium, or in CaF_2 or chalcogenide glasses for lenses or single block multiface mirror systems all with nm level precision;
- Magneto-Rheological Finishing (MRF) which will enable the similar capabilities to those just mentioned for the diamond lathe but with any glass as it is essentially a micro/nano grinding technology;
- high current small spot ion beam figuring technology using a new commercially available source (developed with an Australian University) for either direct ion milling finishing, or for example, for cutting phase plate structures into the back of lenses to enable ultrawide band achromatisation of single element lenses in complex systems.

The objective is not to make what can already be bought overseas, rather to undertake special/advanced fabrication or fabrication in special materials (e.g. DUV or MIR materials). The capability outlined above would enable the fabrication of research based and very specialised high performance optical systems as one offs or in limited volume.

For optical coatings, the intention is to make available and extend the current capability using electron beam evaporated coatings to Ion Beam Sputtered films which offer many well known advantages. The objectives are ultra-uniform coatings over areas up to ~400mm diameter and with nanometre thickness control and high repeatability, ultra-low loss, high damage thresholds, immunity to moisture, many layer capability, etc. Full computer control would allow very complex coatings to be undertaken and devices not possible though other routes, e.g. stable wideband angle tuned narrowband filters, LIGO mirrors, etc. Aside from multilayer optical coatings, the deposition of more exotic materials for research purposes will also be made available for materials that for example cannot be deposited any other known way.

In terms of planar optical devices, the capability would aim to take mature Australian technology in polymers, Germanosilicate, Femtosecond laser written Silica, amorphous

Silicon, Tellurium Dioxide, Chalcogenide, and Lithium Niobate, and provide users with functional chips from the visible to MIR regions using any of the materials above or any combination thereof with already proven low loss Australian developed hybridisation methods. Whilst polymer, Lithium Niobate, crystalline Silicon, and Germanosilicate are commercially available overseas today, costs are high, fast turnaround has proven very hard to achieve, and hybridisation of other materials onto these for amplification or nonlinearity for example is not available. Notably, Australia leads the world in planar optical amplification technology and glass based nonlinear/Mid-IR capability and hybridising these is a potentially transformative step. The proposed capability would make available multi-functional multi-material chips for the very first time. Offerings would include waveguide devices (passive, amplifying/lasing, nonlinear, electro-optic and any combination thereof) and planar sub-wavelength "meta-device" structures. With sufficient support, integration of laser diodes and photodetectors could also be undertaken via flip-chip bonding (this is not new or otherwise unknown technology) to enable full "system on a chip" devices. Integration of 2D materials is also under study in Australia today within several University departments. As planar integration is well recognised to be the key enabler in many of the research fields mentioned above, the availability of custom fabrication will facilitate advanced research of a nature not previously possible in Australia, and also allow fabless start-ups that are also not currently viable.

Lastly, users do not want to receive a collection of parts requiring precision assembly or a chip with no coupling fibres or lenses etc, and so packaging is also a key part of the capability. Aside from the pool of expertise resident in multiple departments of several Universities, the ANFF Optofab node also has runs on the board here. Considerable experience has been gained in packaging chips and specialty optical fibres together with bulk optics in the realisation of astronomical instruments that have for example been put on sky on the Subaru Telescope with considerable success. The proposed capability would integrate the available knowledge and provide a single point of contact to accomplish the packaging required. Capabilities also currently exist in at least one Australian University to certifiably stress test the final device with programmable temperature, humidity, vibration, acceleration, space like conditions, etc. The packaging then enables devices to be deployed in real world research and commercial applications in a way not possible to date in Australia.