DSTO
DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

FACT SHEET - Delivery Fibres for Directed Infrared Countermeasures: Progress and Highlights

Adelaide University component of the 2006 DIRCM CTD program
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Start date of this CTD: 1 October 2006
End date of the Adelaide University component of this CTD: 30 September 2008

Background:

Directed Infrared Countermeasure (DIRCM) systems have the potential to provide effective protection against surface-to-air and air-to-air IR guided missiles by illuminating threats with a high power modulated infrared laser beam. The optical delivery system is one crucial part of aDIRCM system that transports the radiation from the laser source to the turret. Existing DIRCM systems either have the laser co-located with the turret which increases the size and weight of the turret, as well as impacting on through life service, or utilise a complex free-space system, which needs to be customised for each platform fit-out. The development of an optical fibre-based delivery system will allow the laser radiation to be delivered to the turret without requiring continual alignment, and offers a high degree of flexibility in overall system design as well as interoperability between sub-systems and also platforms.

Scope of the Adelaide University participation in this CTD:

Adelaide University has been working to develop the delivery fibres required for DIRCM systems. The approach that has been identified as offering the greatest potential for present needs and scalability for future DIRCM systems is the use of fluoride glass-based microstructured optical fibres (FMOF). Prior to this project, the Optical Fibre

Technology Centre at Sydney University developed a proof of concept for a FMOF, However they did not possess a glass development capability or the advanced fabrication capabilities required to approach the performance required. The program at Adelaide University has required the development of research capabilities in the following areas:

- fluoride glass fabrication and compositional development capabilities
- the design of optical fibres suitable for integration with DIRCM lasers
- the development of technologies for structuring and processing fluoride glass
- capabilities for drawing fluoride glass microstructured fibres

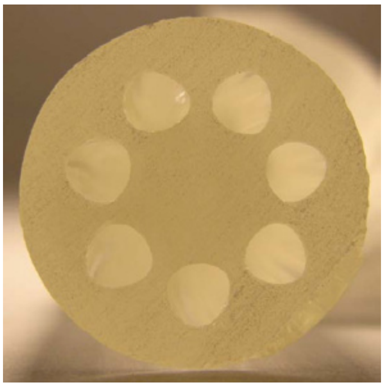
Prior to this CTD, no similar capabilities existed within Australia, and this combination of capabilities is unique internationally. Highlights of progress to date within this program are described below.

Glass melting:

A customised state-of-the-art melting facility has been established for the production of large billets of high-quality fluoride glass. This consists of a controlled atmosphere glove box modified to incorporate furnaces to perform batching, melting, casting and annealing of glass in a high purity nitrogen atmosphere. Using this facility, our initial focus has been on the fabrication of low-loss fluoride glass based on the well-known ZBLAN glass composition. We have also demonstrated the remelting of commercially available fluoride glass (from HOYA Inc.). Both glasses have been used as the basis for fibre fabrication (described further below).

Starting from 30g samples, we have now progressed to the successful fabrication of 200g glass billets. This is a factor of 2-3 times larger than the largest ZBLAN billets ever produced before (to the best of our knowledge). Such large billets are required for the successful production of large mode area microstructured fibres as required for delivering light in DIRCM systems. Building on this demonstration of capability, we are now working to develop new fluoride glass compositions as a means of extending the transmission of these glasses further into the mid-infrared, in order to improve their performance for DIRCM systems.

200g ZBLAN fluoride glass billet



Cross-section of 7-hole ZBLAN preform

Structuring:

We began this work by performing a modelling study aimed at identifying a fibre design to be used as a target for fabrication within this project, bearing in mind the requirement to match the output of the DIRCM laser and to account for fabricated-related constraints. This study identified a simple structure with 7 circular air holes arranged around a large core, and made a range of predictions for the characteristics of the fibres. The approach used here for introducing structure into fluoride glass is extrusion. Our early work identified a new die material suitable for use with fluoride glass. Using these new dies, we demonstrated the first successful extrusion of simple unstructured rods in both commercial HOYA glass and in-house ZBLAN glass. The complex extrusion dies required to extrude the 7-hole preforms were designed and manufactured, and a series of systematic design revisions were performed to improve the mechanical stability of the dies to the level required during the extrusion process. Based on these dies, the extrusion of defect-free HOYA and ZBLAN structured preforms has been demonstrated for the first time.

We have also designed and installed a facility for the HF acid based polishing of ZBLAN glass billets and rods via etching. Currently work is in progress to extend this approach to chemically polish the holes inside a structured fluoride preform. Etching is required to enable the production of strong, lowloss fluoride fibres.

Fluoride fibre drawing:

The Adelaide University fibre drawing tower has been upgraded to enable the fabrication of low-loss fluoride glass fibres. By upgrading the internal configuration of the tower furnace, we have tailored the gas flow around the preform during fibre drawing, and we have now demonstrated excellent fibre diameter control (± 1µm in 100-200µm). By creating an oxygen and moisture-free atmosphere around the preform we have demonstrated the production of crystal-free fluoride fibres. Using a new gravity-fed coating system, we have demonstrated the on-line coating of fluoride fibres, and by installing a preform pressurization system we have enabled the precise measurement and regulation of preform pressure (with 1Pa resolution), thus allowing good control of the hole size during fibre drawing.

These customisations have culminated to date in the drawing of low-loss unstructured ZBLAN fibres from extruded rods and the first ever drawing of microstructured fluoride fibre from extruded structured preforms. In the unstructured fibres, losses of 0.36dB/m @1.5µm have been achieved, of a similar magnitude to commercially available ZBLAN fibres (0.15dB/m @1.5µm). In the mid-infrared, measurements of these fibres at DSTO have yielded losses of 1.0 dB/m @4.0µm and 5.5 dB/m @4.7µm. These loss levels are comparable to the best available commercial fibres, and there is significant scope for further loss reductions via improved glass and fabrication refinements. Summary: This project promises to deliver the capability required to produce mid-infrared fibres with high beam quality and large mode area for DIRCM applications and beyond. Thus far within this CTD there have been significant technology achievements in the development of fluoride glasses, advances in glass structuring technologies, and the demonstration of a capability to produce low-loss fibres in the mid-infrared.