

Towards environmentally-insensitive fiber interferometers up to MIR

STSM results report

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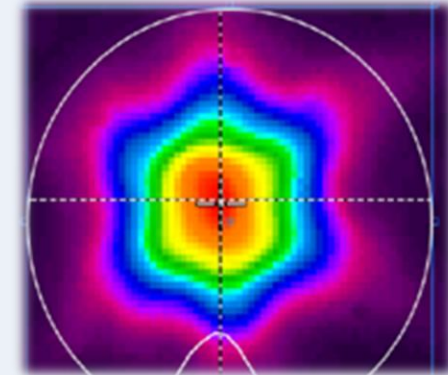
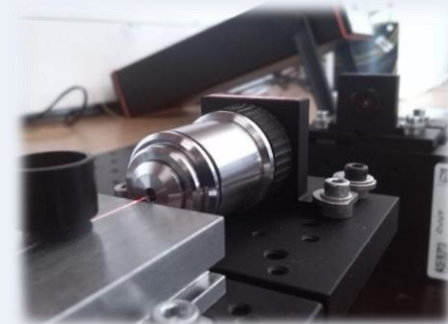
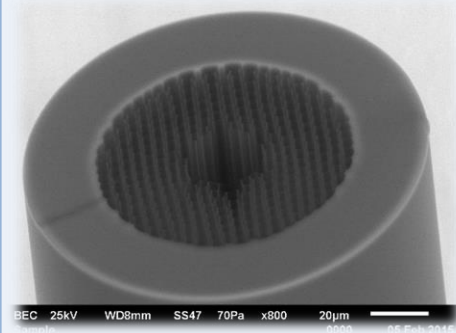
Dr. Radan Slavík (ORC)

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Southampton



Content

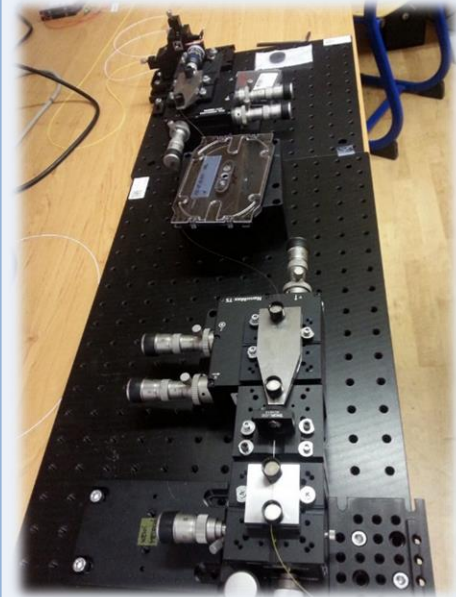
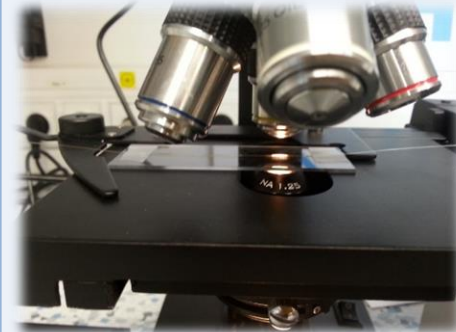
- STSM details
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STSM

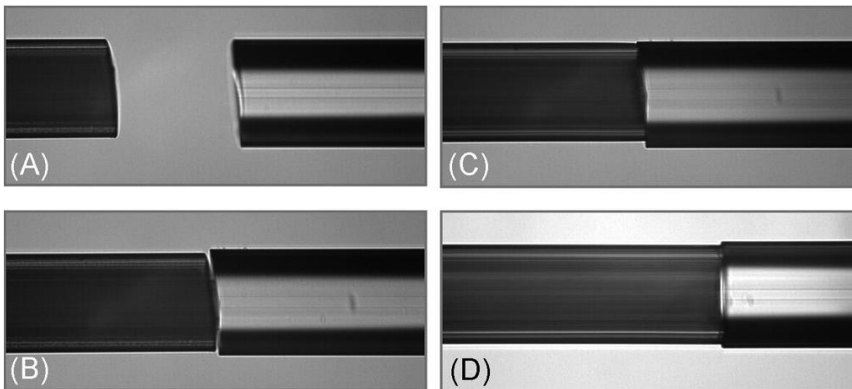
- **Optoelectronics Research Centre, Southampton**

- Carried out from 13. March to 13. April
- I am an ECI
- **Focus:** Hollow-core photonic bandgap fibers (HC-PBGF) for NIR/MIR applications
- **Goals in brief:**
 1. Optimization of splice-less connection of HC-PBGF with emphasis on return loss mitigation.
 2. Characterization of HC-PBGF module.
 3. Specific application in an interferometric configuration.
 4. High-precision measurements based on thermally-insensitive HC-PBGF with reduced reflections



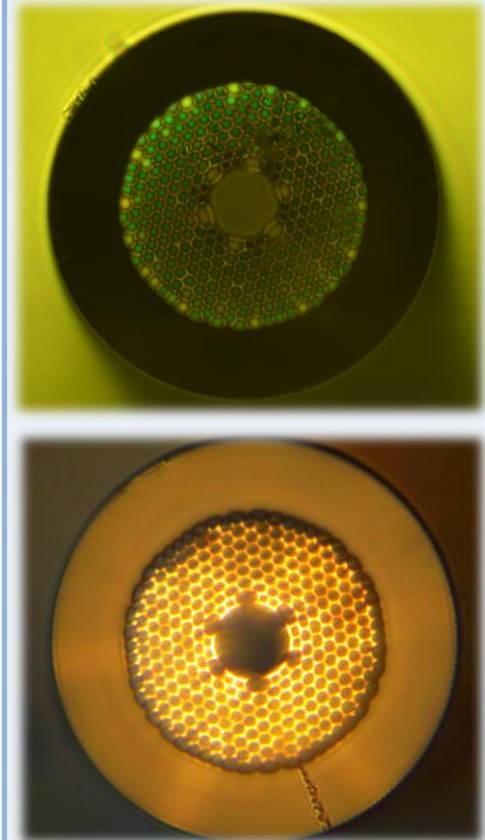
Motivation

- **Transmission in MIR**, low-dispersion, low-losses
- **18x lower** temperature sensitivity vs SMFs
Slavík, R. et al. Ultralow thermal sensitivity of phase and propagation delay in hollow core optical fibres. Sci. Rep. 5, 15447; doi: 10.1038/srep15447 (2015).
- Ideal for time-transfer and interferometry
- Splicing of HC-PBGFs does not eliminate reflections
- Angle-cleaving of HC-PBGFs is extremely complicated



RL = 44 dB
IL = 3 dB

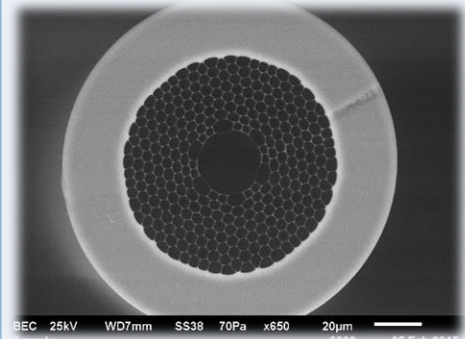
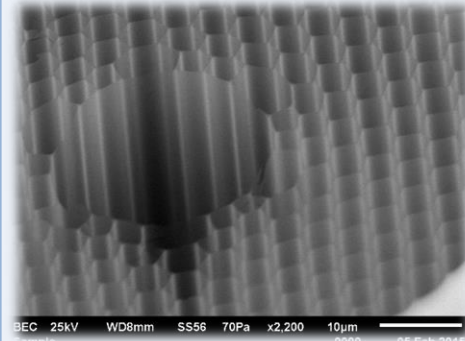
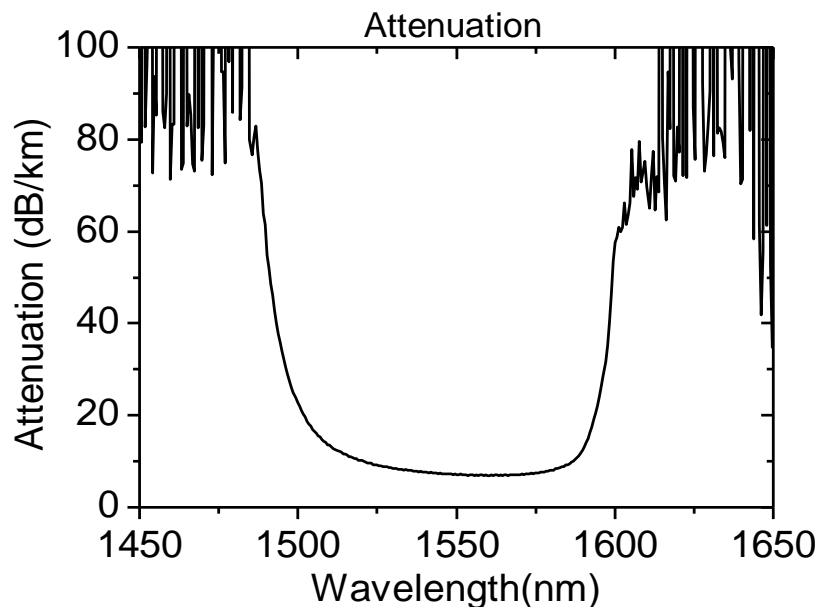
F. Couny, F. Benabid and P. S. Light, "Reduction of Fresnel Back-Reflection at Splice Interface Between Hollow Core PCF and Single-Mode Fiber," in IEEE Photonics Technology Letters, vol. 19, no. 13, pp. 1020-1022, 2007



Studied fibers

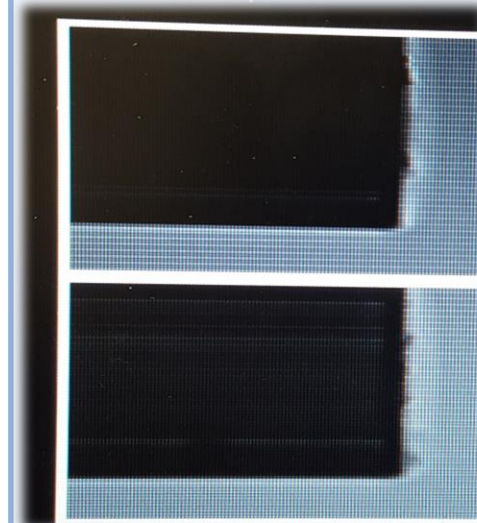
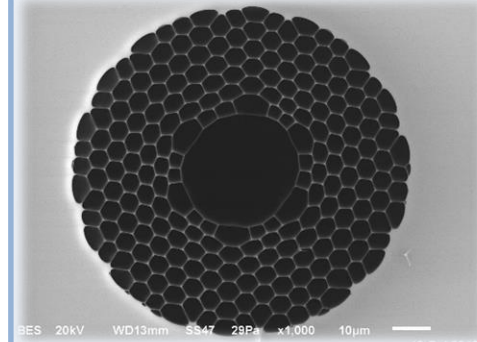
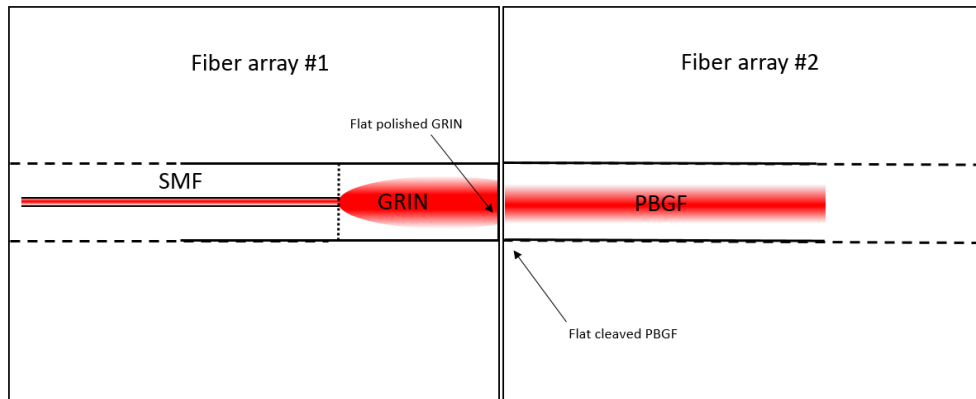
- **Hollow-core photonic bandgap fiber**

- 19-cell defect
- 170 μm /130 μm outer diameter
- MFD 21.5/16.0 μm (@ 1550 nm)
- NA = 0.06
- Only 0.3 % of signal in silica, 90 % air-filling



STSM (cooperation) aims

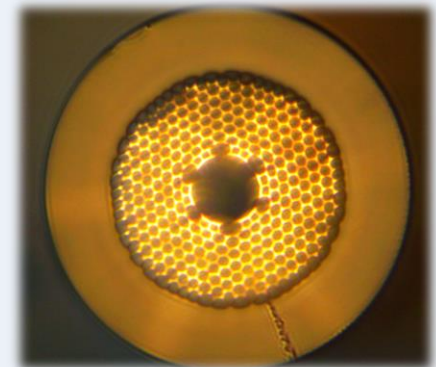
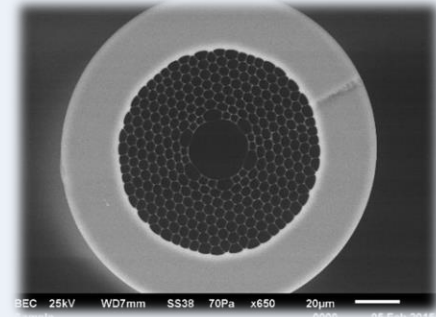
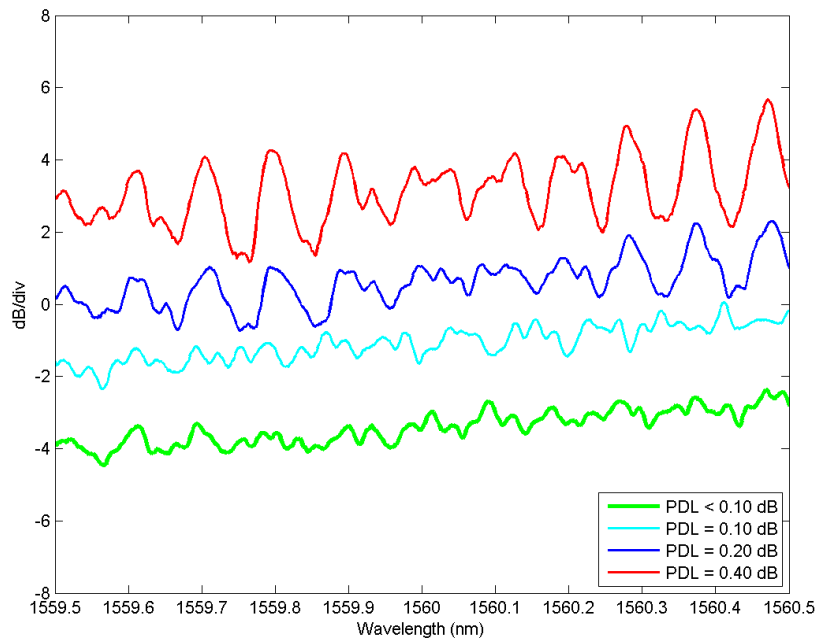
- **Develop and prepare a HC-PBGF connection**
 - Overall insertion loss below 2 dB
 - Return-loss better than 60 dB (at least 50 dB)
 - Polarization-independent (strictly single-mode)
 - Stable and portable
- Fiber-array approach



Polarization effect mitigation

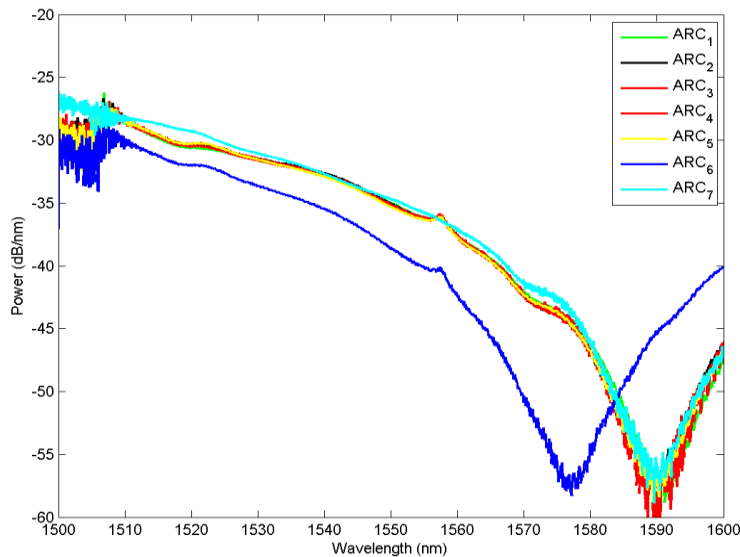
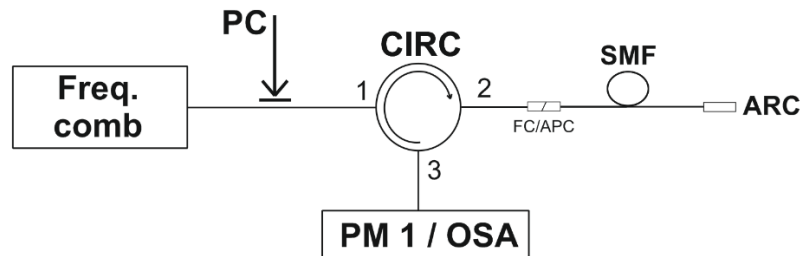
- **Monitoring broadband spectrum**

- Polarization dependent loss must be under 0.1 dB
- Then we can say the connection is single-mode
- Cleave of HC-PBGF is never ideal

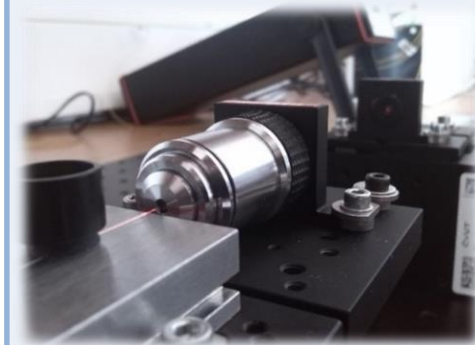
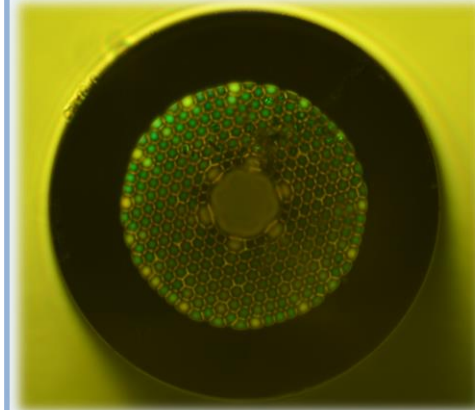


Return loss mitigation

- Antireflect coatings study



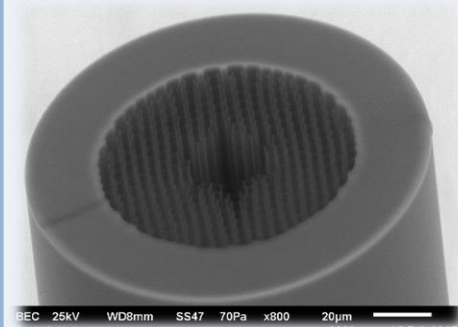
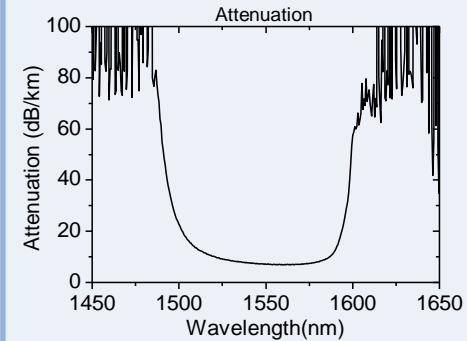
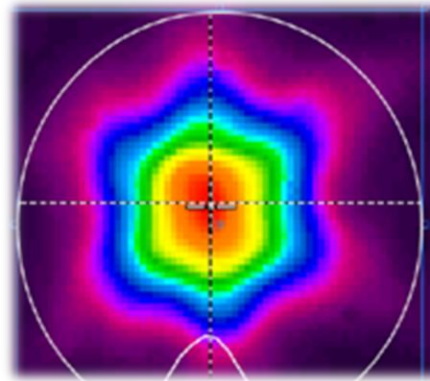
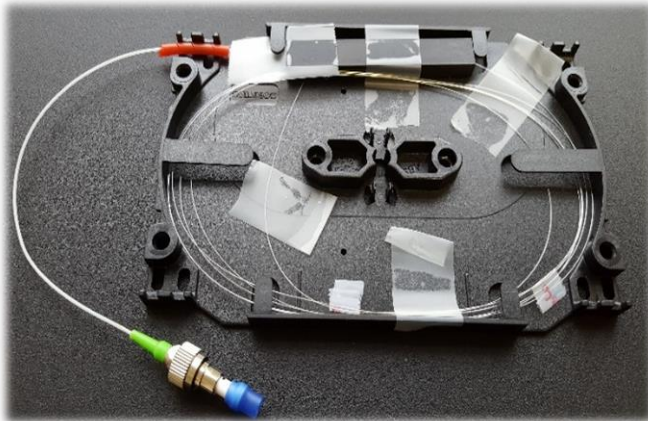
RL > 43 dB
in a very
narrow BW



LMA fiber results

- **Large-mode area fiber approach**

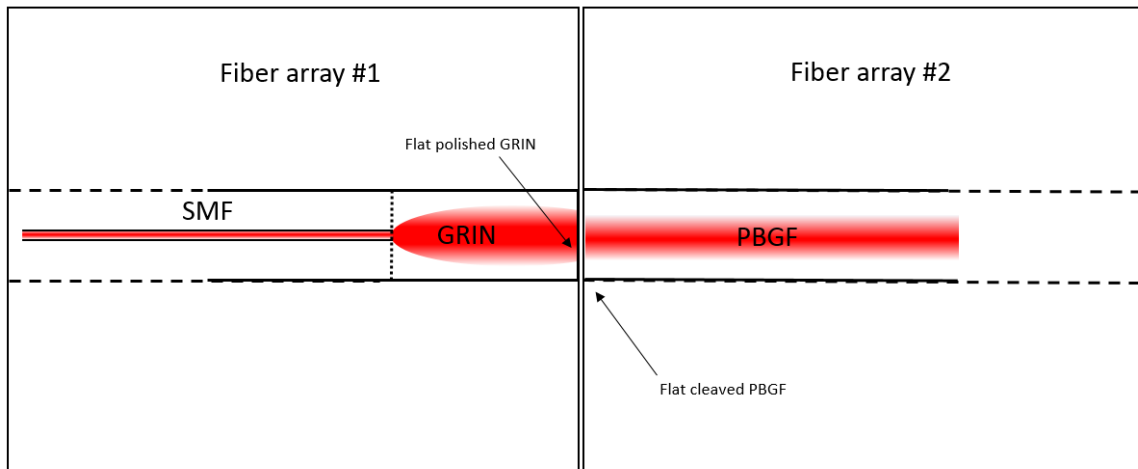
- Requirement for custom fiber being drawn (SM, MFD $15\text{ }\mu\text{m}$)
- Low IL at the LMA-HC-PBGF connection... 0.3 dB
- Higher IL at LMA-SMF splice... 0.5-1.0 dB (can be mastered)
- Does not require single-mode regime (polarization dependence) measurement



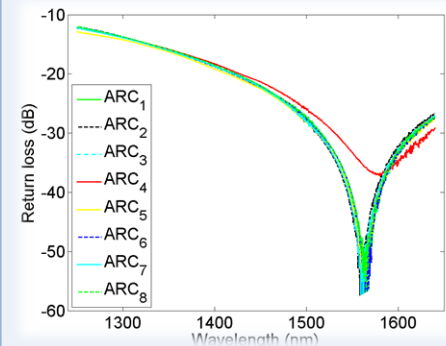
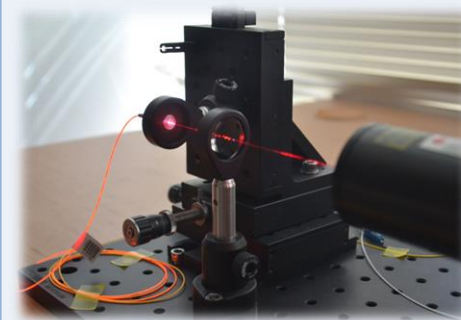
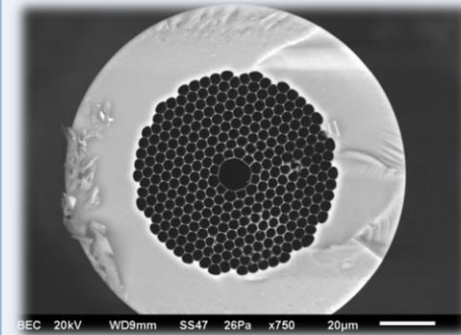
GRIN endcap results

- **Endcap (GRIN lens) approach**

- Not so precise MFD/NA matching as with LMA
- Commercial multimode fibers (GRIN) available
- GRIN length tailoring required for a specific HC-PBGF
- Polarization dependence (single-mode regime must be studied)

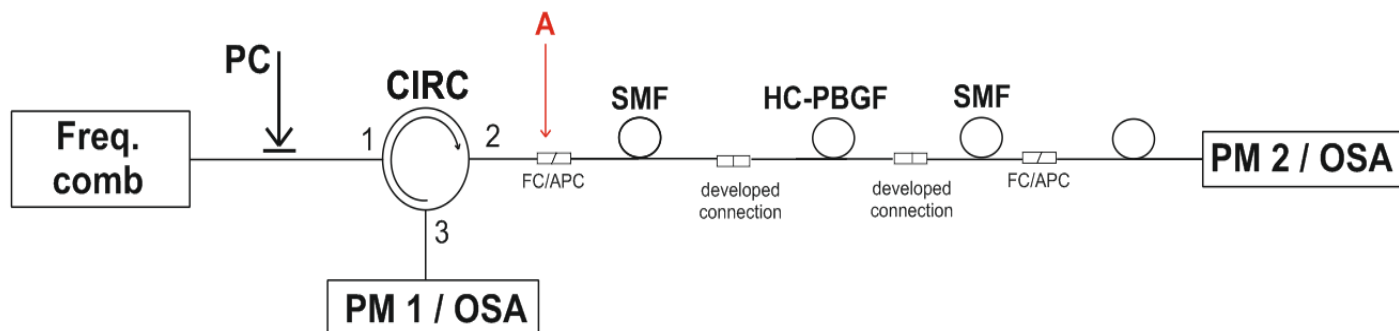


- Once cleave is not ideal, angle matching must be performed
- Currently best IL at 0.9 dB per boundary



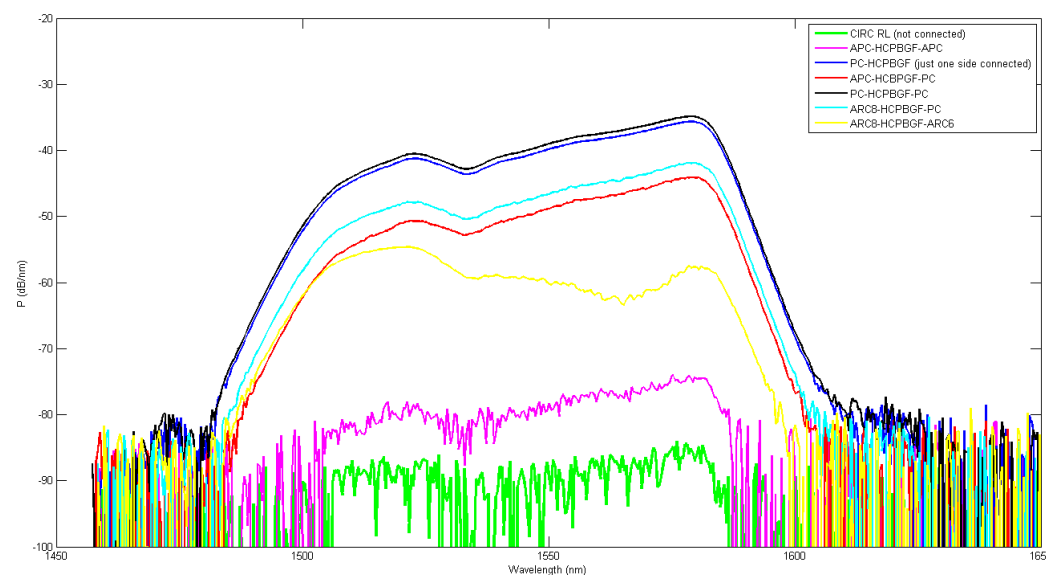


HC-PBGF module



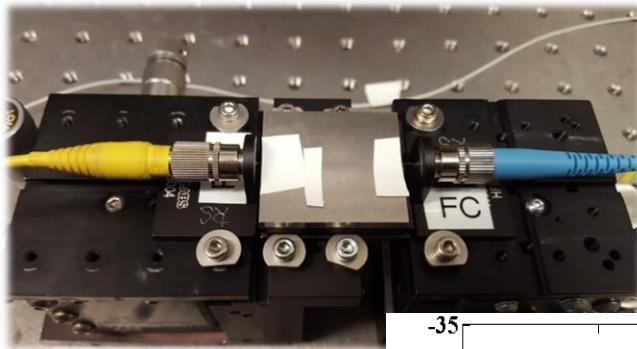
1. With ARCs improvement of more than 20 dB compared to 4% Fresnel reflection

2. With APC input + PC output we are far below the ARC performance

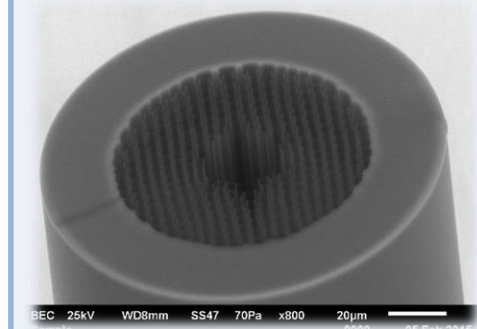
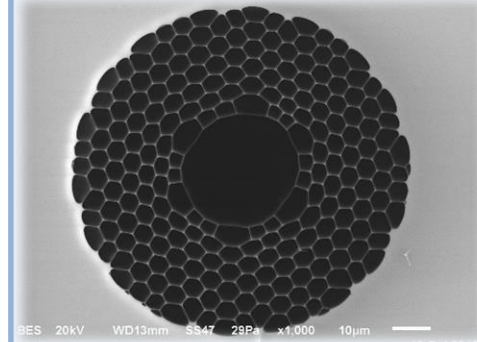
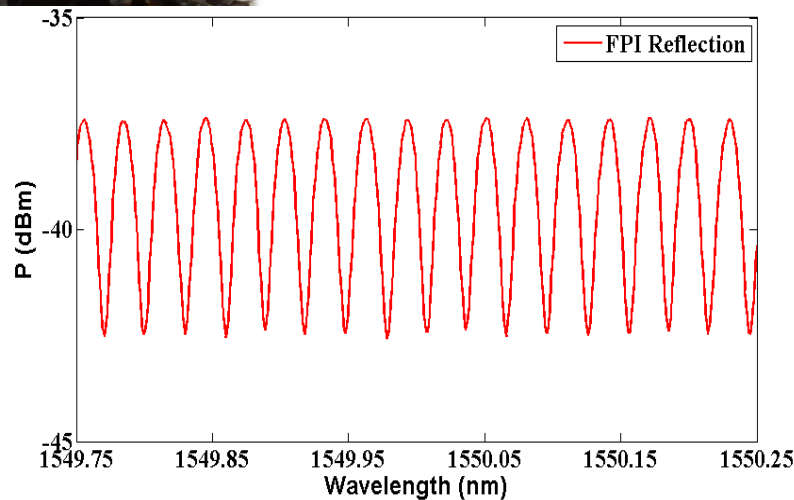


Fabry-Perot experiment

- Use of a splice-less connection
- Can profit from ARC deposition
 - In this case with high reflectivity

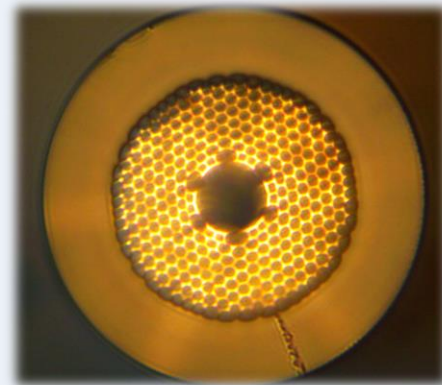
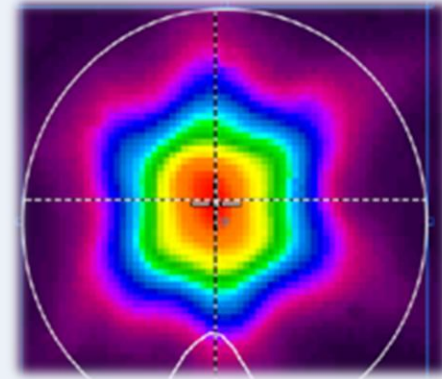


32mm-long PBGF segment
Flat boundaries (SMF/PC)



Conclusion

- Splice-less connection already verified on in-house drawn LMA fiber, where we achieved 0.3 dB IL for a single HC-PBGF connection
- Currently working on technology improvements toward $RL > 60$ dB with angled GRINs
- IL of the whole system currently at 2.4 dB in the single-mode regime (1.6 dB with perfect cleaves)
- Possible to employ this technology for other types of HC fibers
- Journal paper under preparation



Thank you for your attention

