MOCCA ESRs' Newsletter

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MOCCA ESR Vassiliev Victor's project:
"Tuneable SNAP resonators"

MOCCA ESR Victor Vassiliev presents his project.

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ABOUT MY PROJECT AND ITS PROGRESSES

The aim is to create a fabrication method for tuneable whispering gallery mode optical micro resonators using the surface nanoscale axial photonics (SNAP) platform. Establishing such a method opens the door to applications such as comb generation.

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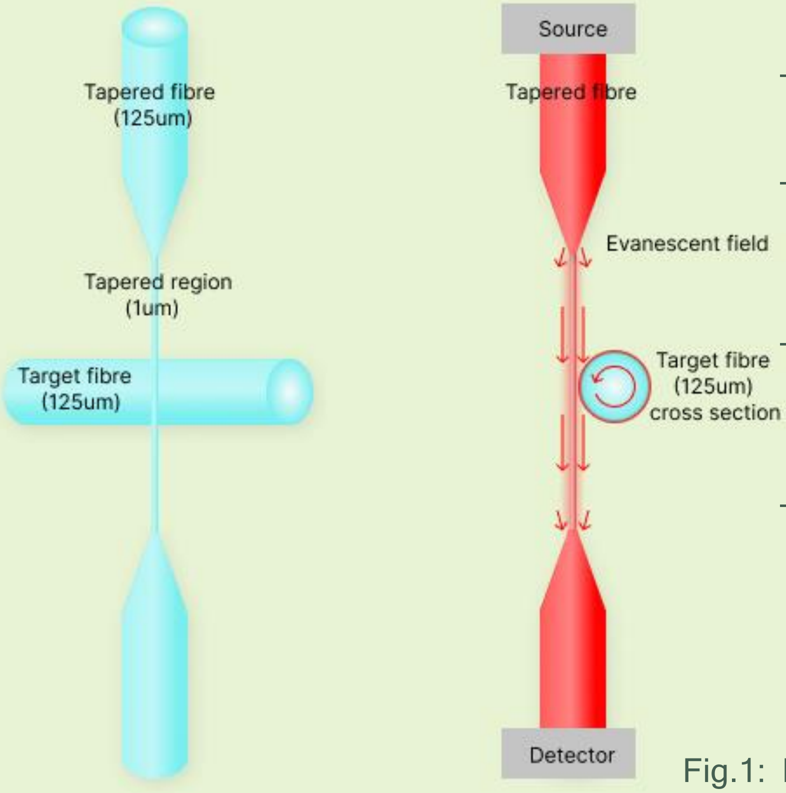
SNAP is a well-established & sustainable platform using a simple setup:



- A 125um fibre is connecting the source and the detector of an Optical Analyzer.
- A region of the fibre is tapered down to 1um creating a strong evanescent field around the tapered region.
- The target fibre is positioned perpendicularly allowing the evanescent field to excite WGMs in it.
- The Optical Analyzer computes the Insertion loss diagram giving us indirect information about which frequencies have been coupled to the target fibre.

Fig.1: Basic SNAP setup.

The whispering gallery modes of light, which circulate close to the surface of the optical fibre and slowly propagate along its axis are very sensitive to any effective fibre radius variations (combined influence from the radius and the refractive index variations). This allows us to localize light with nanoscale radius variations.

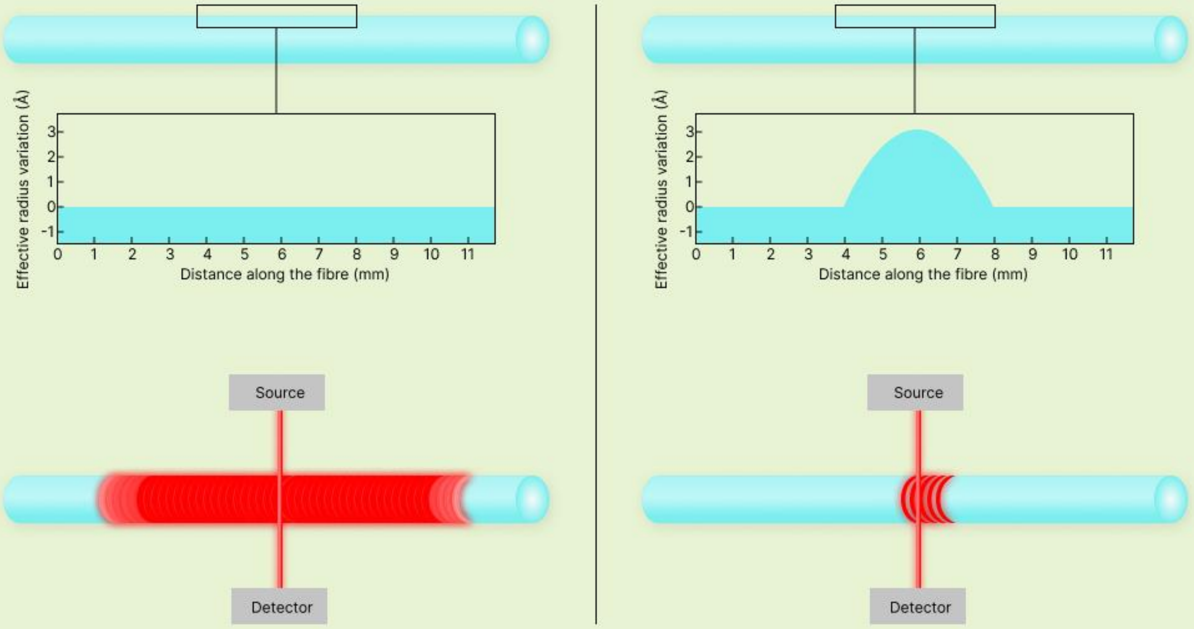


Fig.2 WGM localisation with a SNAP nanostructure.

Therefore, establishing how to introduce this nanoscale radius variation is key for this technology. Previously we considered altering the fibre using heat, in this publication we demonstrate the fabrication with angstrom precision using a flame: https://iopscience.iop.org/article/10.1088/1612-202X/ac61d4

However, not introducing any permanent changes to the fibre could allow the fabrication of a truly tuneable WGM micro resonator, this is exactly what we're aiming for by coupling a bent fibre to the basic SNAP setup:

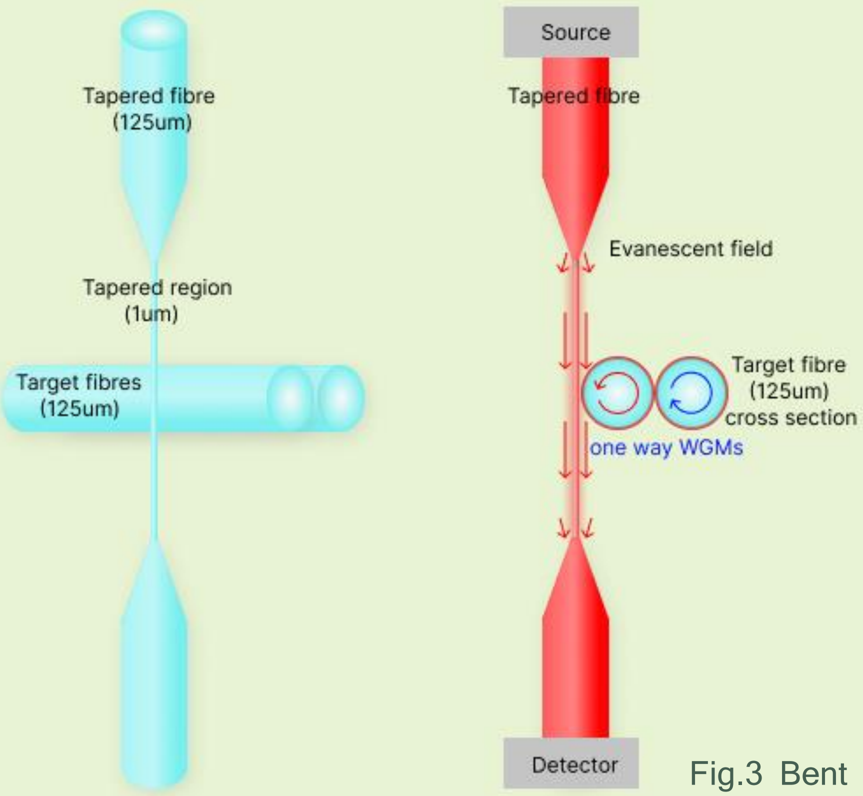


Fig.3 Bent fibre coupling

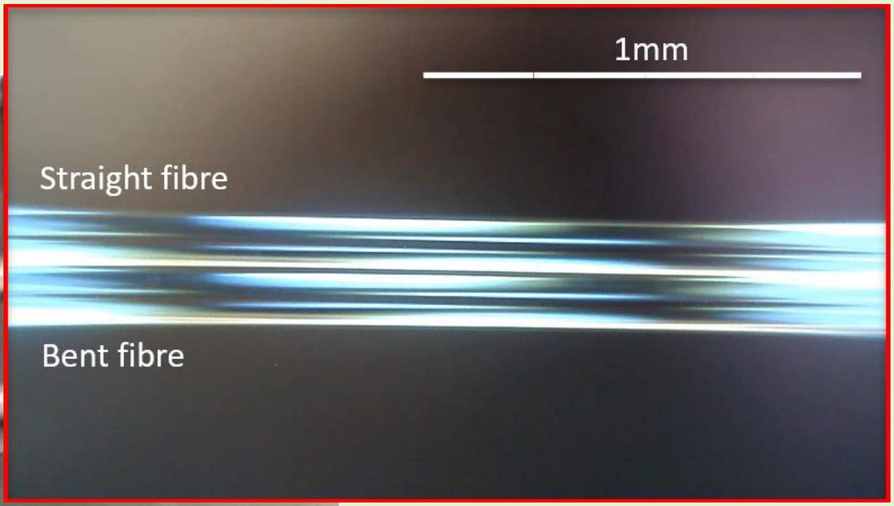


Fig.a Zoom on the contact area (top view)

The curvature is not visible at this scale.

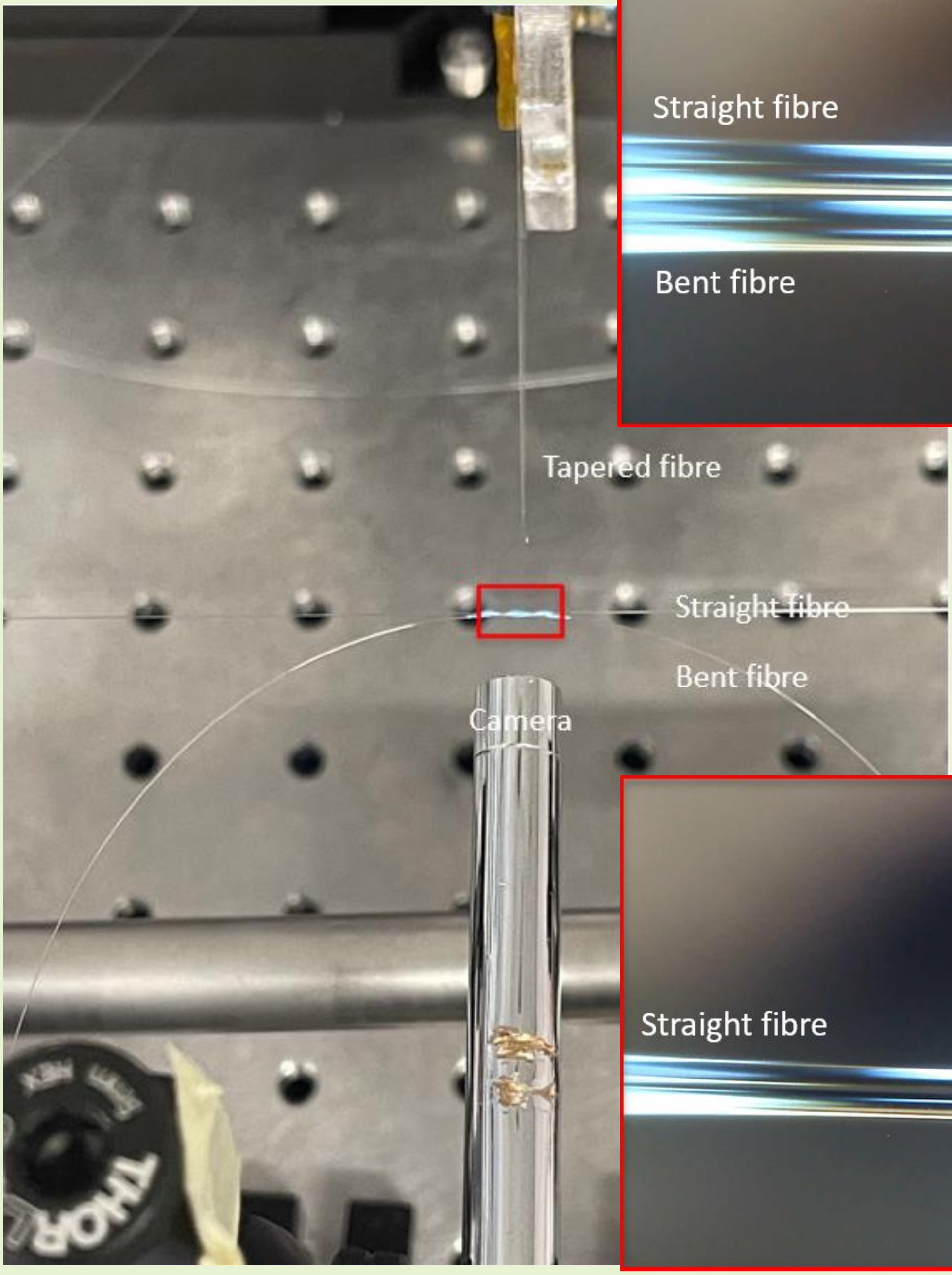


Fig.4 Bent fibre coupling setup (top view)

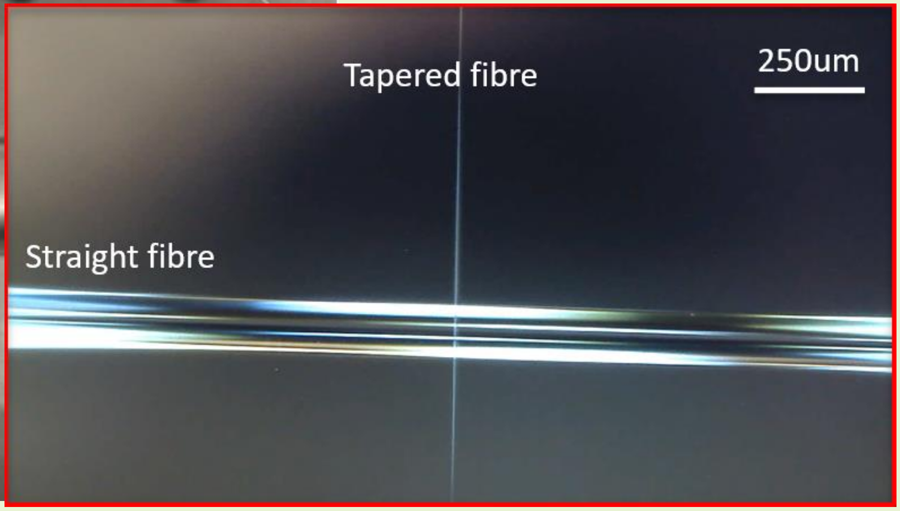


Fig.b Zoom on the contact area (side view)

The bent fibre is hidden by the straight fibre

This setup allows to localize light in the area where the fibres are coupled, different resonators can be made depending on the curvature of the bent fibre:

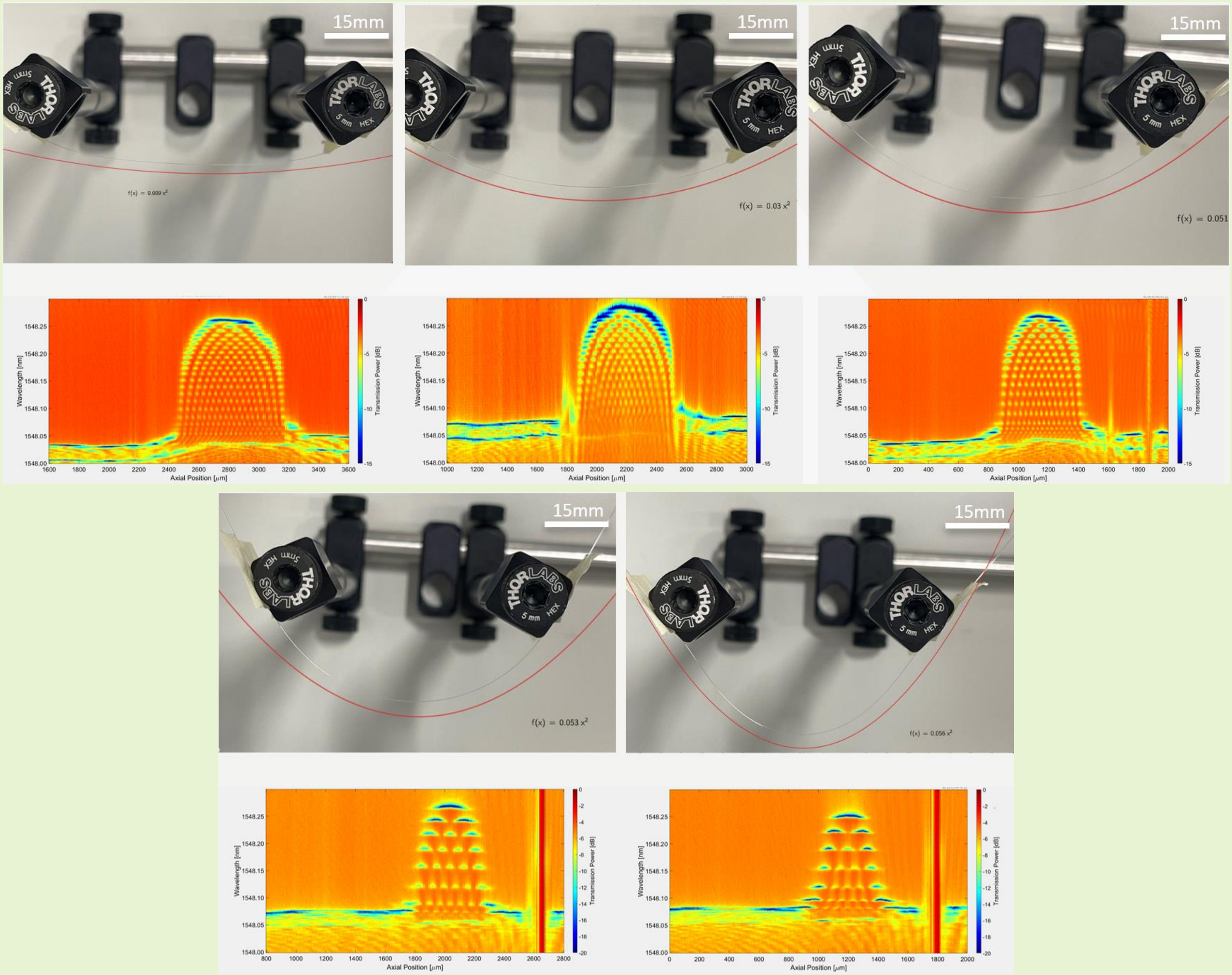


Fig.5 Controlling the micro resonator shape by changing the curvature of the bent fibre.

The resonators go from .5mm to 1mm wide, and by approximating the bent fibre's curvature near the contact point we can find the distance below which the interaction between the two fibres is possible:

$0.009*(.5)^2$ = 0.00225 = 2.25um

$0.056*(.25)^2$ = 0.00350 = 3.50um

The two fibres are affected by each other's static changes which changes the curve near the contact point and makes curvature approximation-based predictions less accurate, however we can say that this critical distance is micron scale.

We also expanded our understanding of the coupling with the tapered fibre, It is a crucial part of the SNAP platform as it plays both the roles of a coupler, exiting WGMs in the target fibre and a sensor allowing us to characterize our devices. Let's first remind how we use it: the main tool for characterisation is the spectrogram. It is assembled from a series of regularly spaced scans performed by the Optical Analyser along the target fibre. The scans show the insertion loss for a range of wavelengths centred around 1550nm:

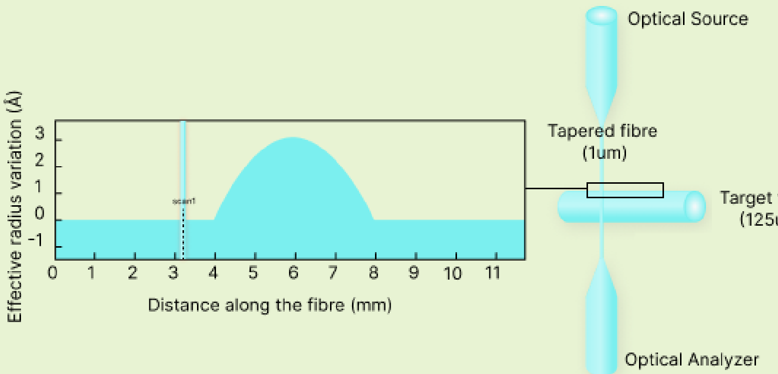


Fig.6a Taper position for the first scan

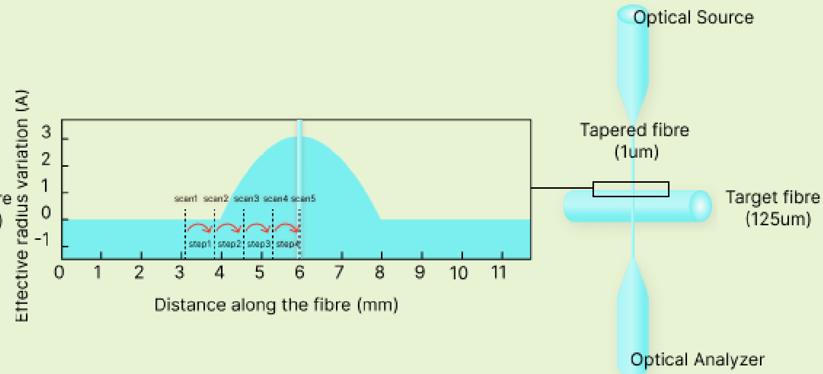


Fig.6c Taper position for the fifth scan

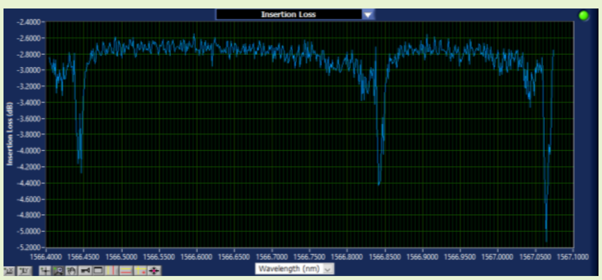


Fig.6b First scan

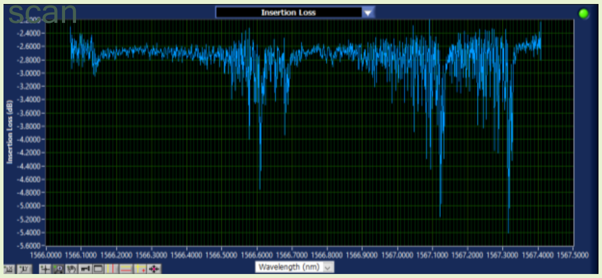


Fig.6d Fifth scan

The spikes in insertion loss indicate the frequencies that went inside the target fibre. For the first scan, the taper was positioned outside of the bottle resonator, and we only observe the cutoff wavelengths of the fibre. The second scan was taken inside of the resonator and we see many frequencies corresponding to the resonant modes. The spectrogram is created by juxtaposing Insertion loss scans taken along the target fibre axis.

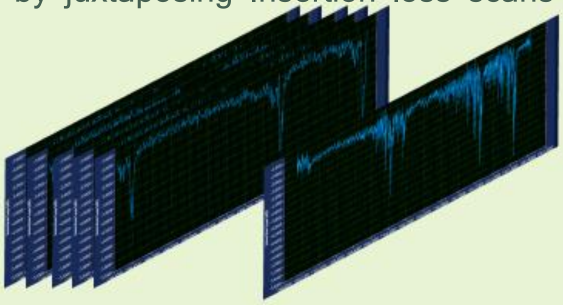


Fig.7a Visual representation of the building process of a spectrogram using equally spaced Insertion loss scans along the target fibre axis.

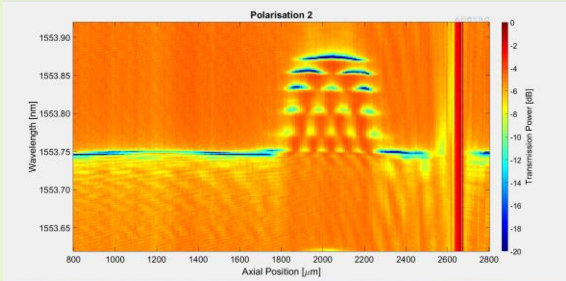


Fig.7b The spectrogram obtained. Each vertical line is one Insertion Loss scan.

We can apply a similar reasoning to learn more about the coupler itself:

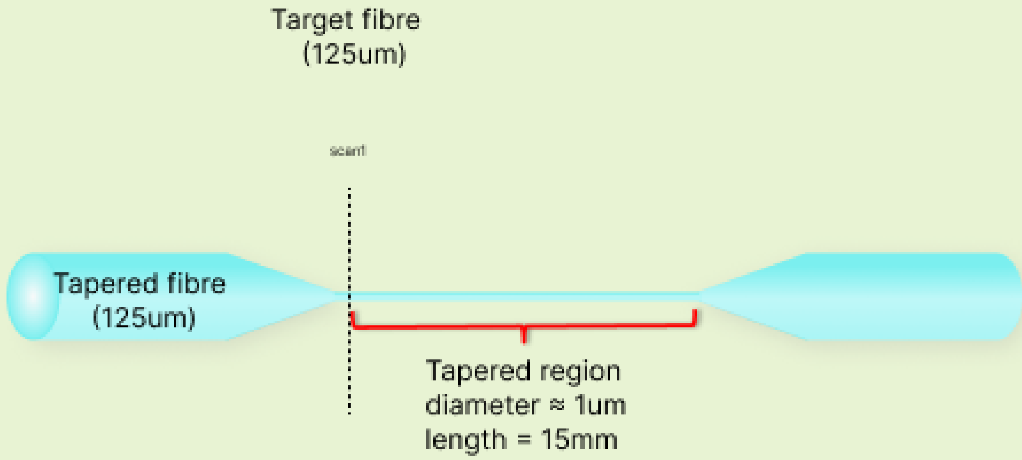


Fig.a: Initial position for the scanning of the taper

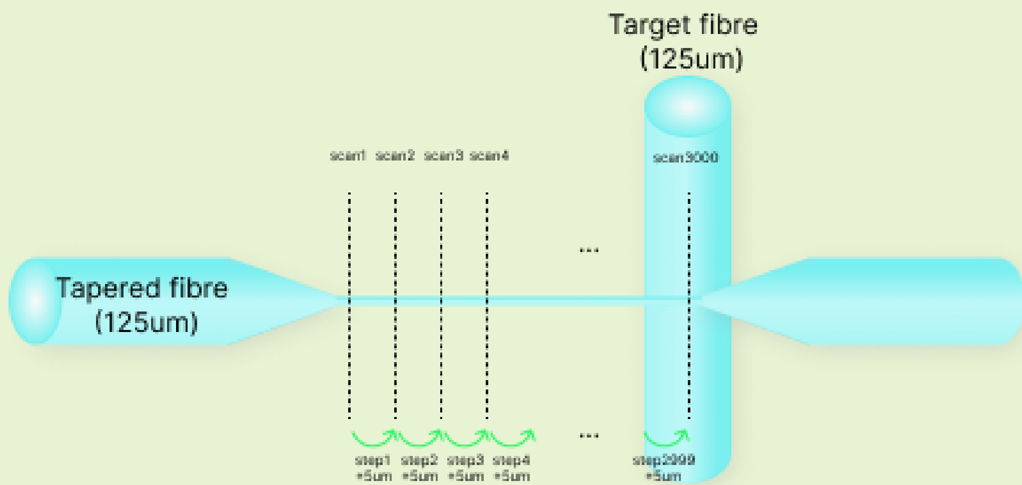


Fig.b: Final position for the scanning of the taper
(3000 scans separated by 5um to cover the 15mm tapered region)

Fig.8 Scanning the tapered fibre.

The tapered region is not perfectly uniform and Insertion Loss scans from the same point of the target fibre will vary with the coupling position along the tapered fibre.

To ensure repeatability we need to find the best coupling position and to determine regions of the taper that are sufficiently homogeneous we make a spectrogram of the taper itself.

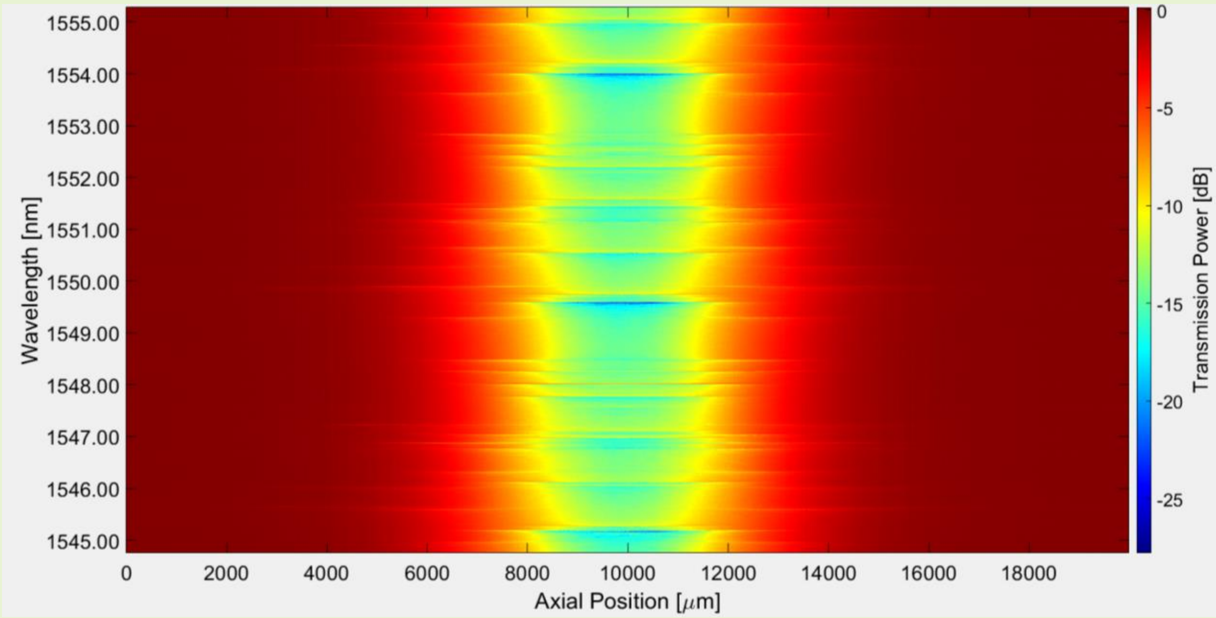
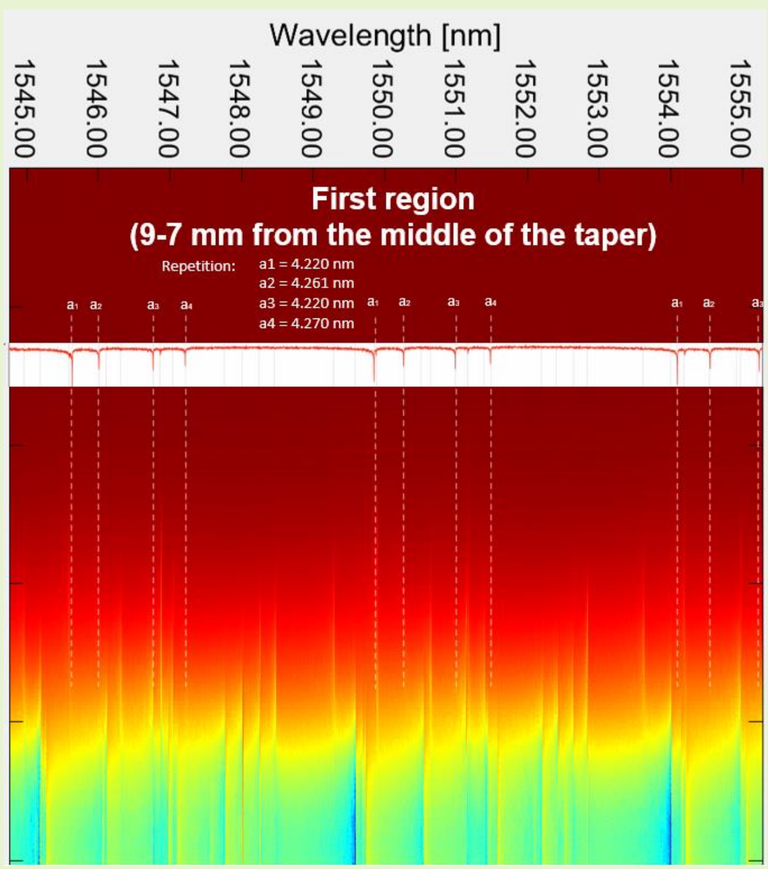
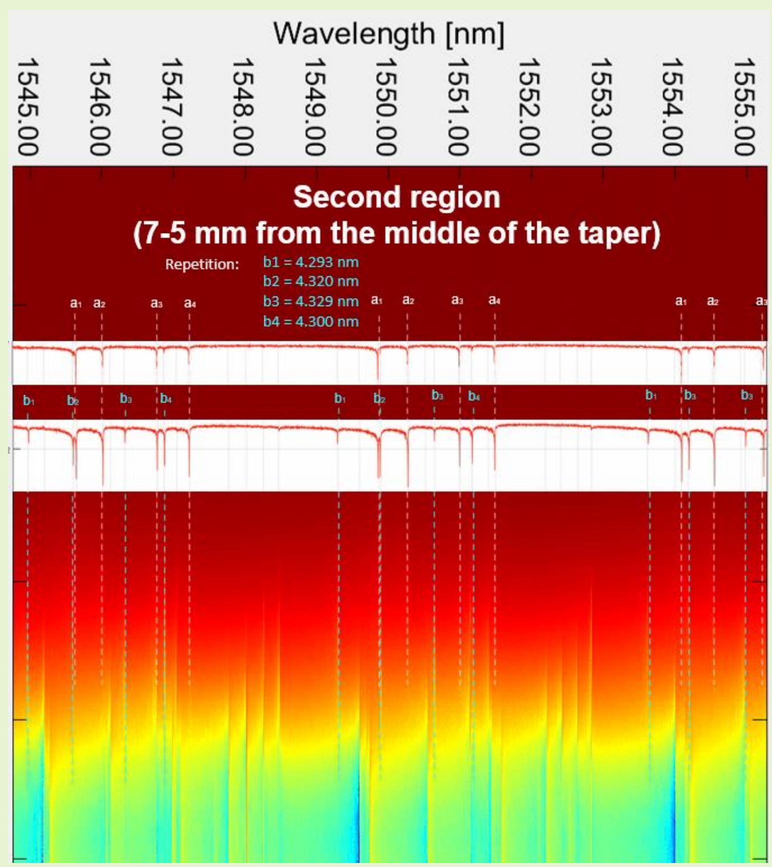


Fig.9 Spectrogram of a tapered fibre commonly used for SNAP characterisation

The obtained spectrogram shows the different wavelengths coupled into the target fibre depending on the position along the taper with 10mm being the centre of the tapered region. The tapered fibre gets thinner as we approach the centre of the tapered region. We can identify four regions with consistent insertion loss:





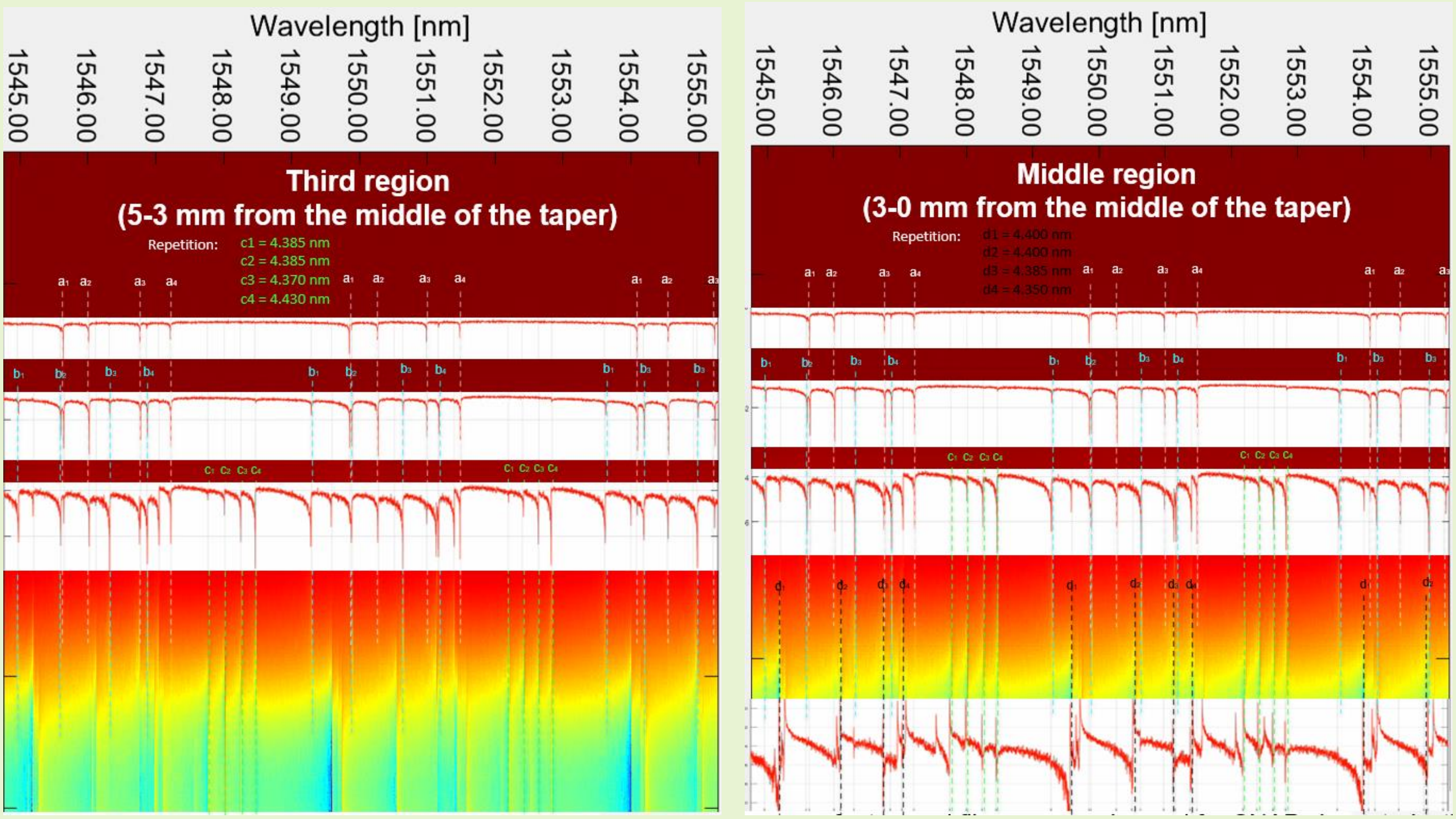


Fig.10 Four regions of the tapered fibre

The cutoff lines repeat every 4.2nm or so however they are not affected in the same way by the micro resonator:

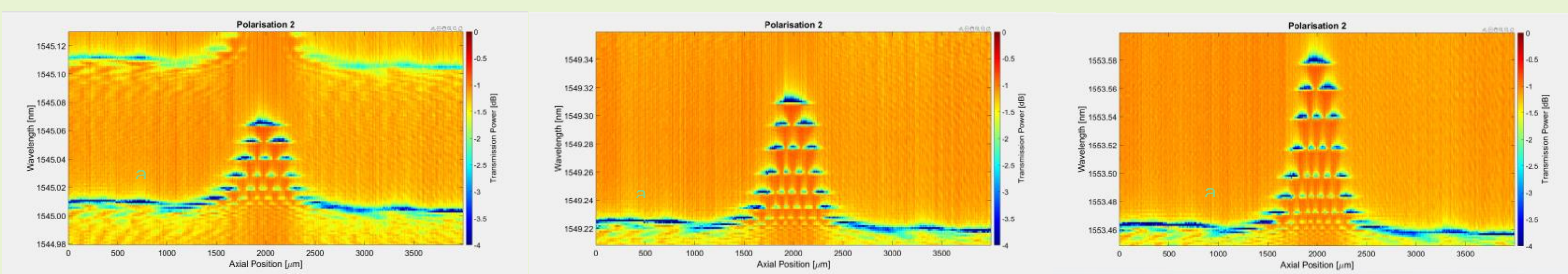


Fig.11 We observe the same sample at different repetitions of the cutoff a3 1545.02nm, 1545.02+4.220 = 1549.24, 1545.02+4.220+4.220 = 1553.46nm

Different iterations of the a3 cutoff give very different resonances, this wouldn't be a problem for the characterisation of micro resonators if they consistently appeared at the same wavelength however, by comparing the spectrograms of different tapered fibres obtained following the same procedure we observe:

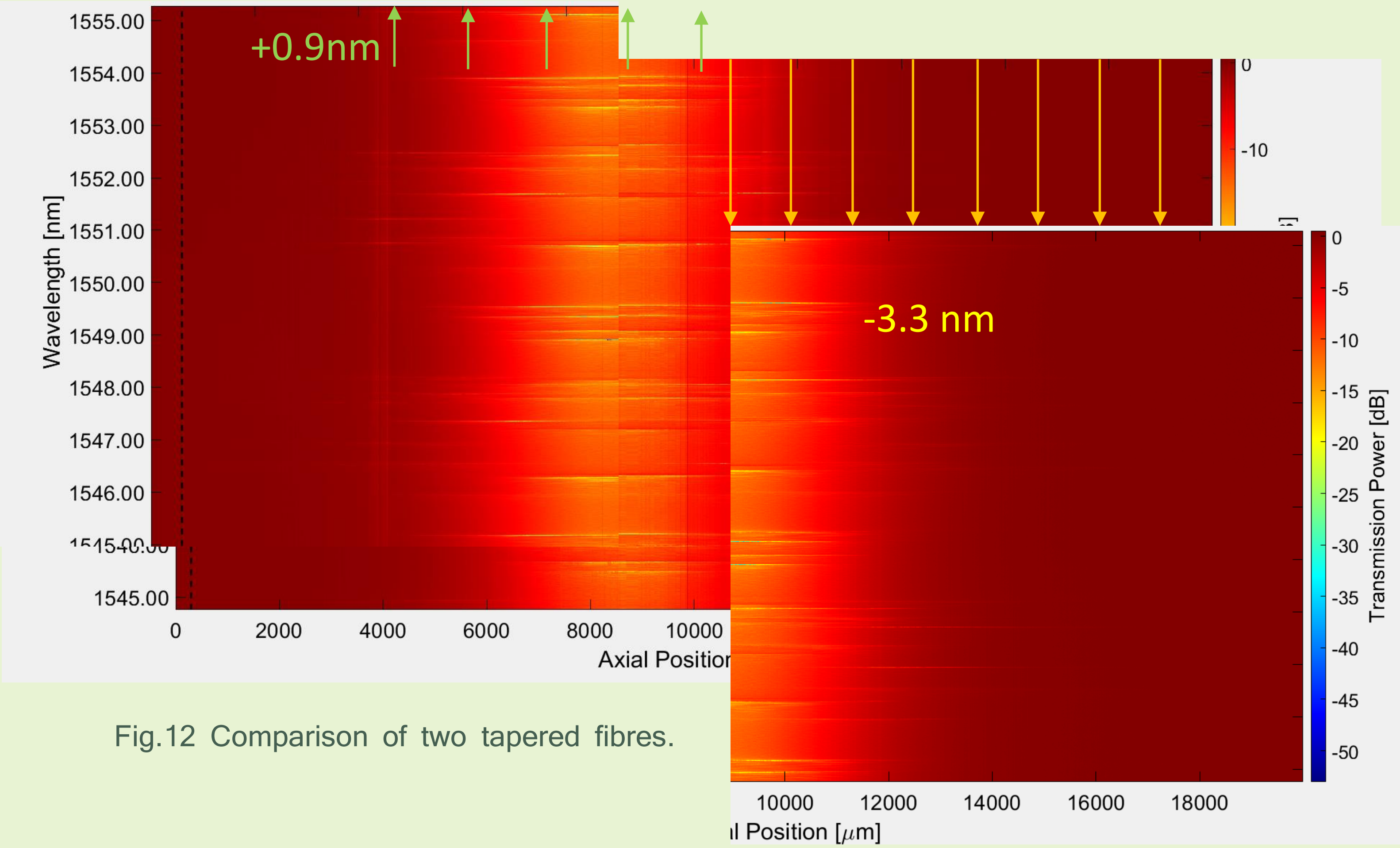


Fig.12 Comparison of two tapered fibres.

The same pattern can be observed in both tapered fibres however there is a +.9nm (or -3.3nm) shift between the two. Combined with the fact that cutoff repetitions can drastically differ, this poses a problem for reliable characterisation. And underlines the need for a better understanding of the coupling that occurs.

Finally, it appears that a small (0.5mm) positioning error along the tapered fibre axis can drastically alter the structure observed:

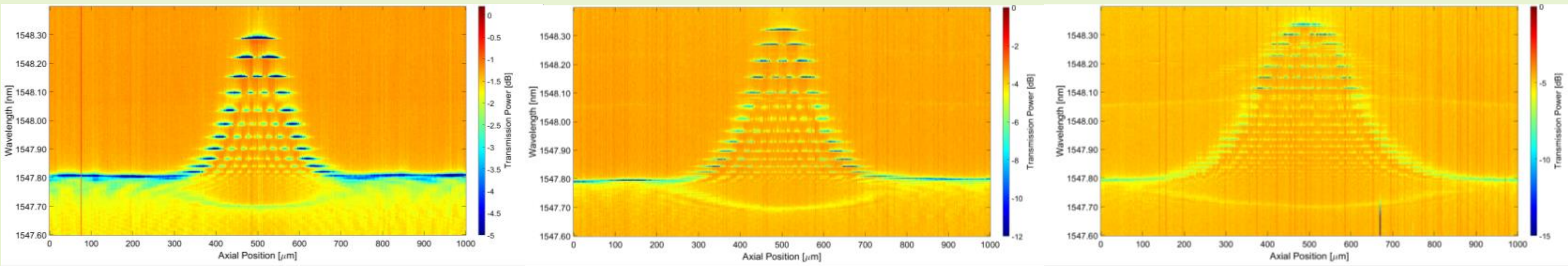
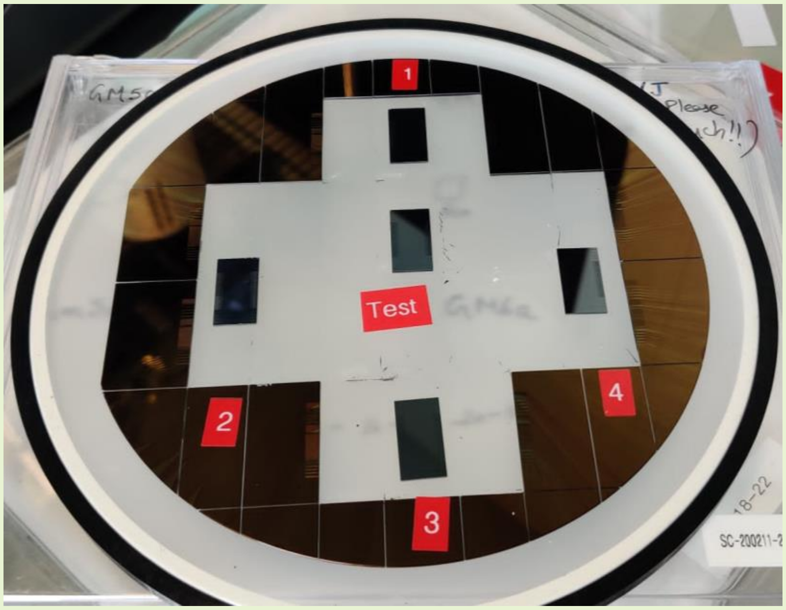


Fig.12 Spectrograms of the same structure at 6mm, 5.5mm and 5mm from tapered region's centre respectively.

Thanks to the help of AMO's team, it has been shown that the tapered fibre can successfully be replaced by a coupler on chip.



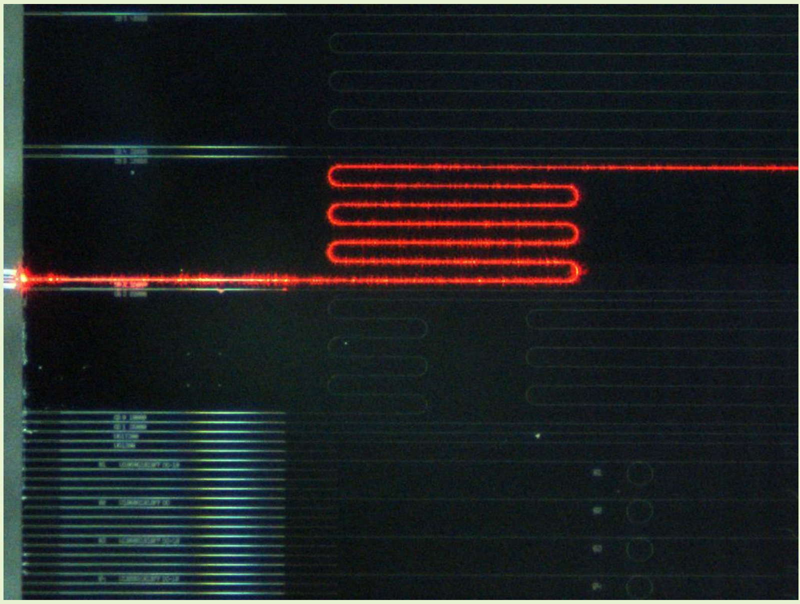


Fig.13 Waveguide was used instead of the tapered fibre. (With significantly higher losses)

Aside from the fabrication and characterisation, progress was also made in experimental data processing and experimental artifact removal.

You can follow the progress of MOCCA ESR's research on our blogs and social media:
See https://mocca.astonphotonics.uk/blog/

MOCCA_EID is a project coordinated by Aston Institute of Photonic Technologies, Aston University Birmingham.

AIPT
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MOCCA's Partners:

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