# Anomalous spectral behaviour of weakly-fused optical fibre couplers with sub-micron diameters

***Rand Ismaeel*[†]*, Wanvisa Talataisong*[†]*, Marcelo A. Gouveia, Martynas Beresna and Gilberto Brambilla***

*Optoelectronics Research Centre, University of Southampton, SO171BJ, Southampton, UK.*

[†]*These authors contributed equally*

Weakly-fused optical fibre couplers can be simplified as a system of two optical fibre tapers, which are often called nanofibers when having sub-micron diameters. While conventional optical fibre couplers exhibit a wide spectral region of modal interference where two modes provide a continuous oscillatory behaviour associated to the large difference between phase constants of interfering supermodes [1], nanofiber couplers (NFC) exhibit an anomalous behaviour (Fig. 1) in close proximity to the supermodes cut-off wavelengths, where the high extinction ratio oscillations can exhibit a very slow oscillation. This region of interest exhibits flat transmission over nearly 20 nm and results from the variation of the supermodes dispersion near their cut-off. This hybrid behaviour, where a flat transmission region is proximal to rapid spectral oscillations, allows the NFC to operate at high sensitivity as well as large dynamic range for application related to optical detection.

The NFC was fabricated from two standard telecom fibers (Corning SMF-28) using the modified frame brushing technique [2], in which the geometry of the coupler is controlled as described previously in [3], to maintain an adiabatic behaviour throughout the pulling process.

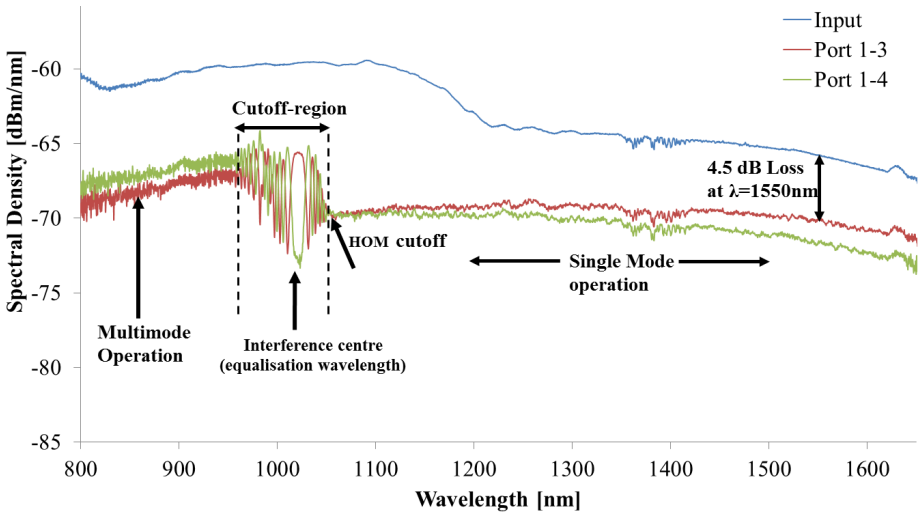


**Fig. 1** Output spectra of the nano fibre coupler, where the taper waist diameter is d~700nm. While at short wavelengths the coupler multimode operation produces an irregular spectral behaviour, at longer wavelengths the presence of one supermode implies the lack of oscillations. At wavelengths where two supermodes are present, strong oscillations are observed. An anomalous region can be clearly observed at the equalization wavelength.

The coupler output of both ports was monitored in-situ, using a broadband white source and two optical spectrum analysers. For diameters in the region of 40µm, an oscillatory behaviour starts to appear in the spectrum, showing modal interference between the two supermodes propagating in the coupler waist region. The frequency of these spectral oscillations constantly increases for decreasing of the coupler diameter. When the coupler diameter is reduced to values below 1µm, an anomalous behaviour appears, where the interference centre (equalization wavelength) produces a slowly oscillating region. The equalization wavelength bandwidth constantly decreases for decreasing coupler diameters, a behaviour attributed to the increased speed of these supermodes at the cut-off wavelength.

## References

[1] D. Káčik, I. Turek, I. Martinček, J. Canning, N. Issa, and K. Lyytikäinen, "Intermodal interference in a photonic crystal fibre," Opt. Express 12, 3465-3470 (2004).

[2] G. Brambilla, F. Xu, P. Horak, Y. Jung, F. Koizumi, N. Sessions, E. Koukharenko, X. Feng, G. Murugan, J. Wilkinson, et al., "Optical fiber nanowires and microwires: fabrication and applications," Adv. in Opt. and Photon. 1, 107-161 (2009).

[3] T. Birks and Y. Li, "The shape of fiber tapers," J. Lightwave Technol. 10, 432{438 (1992).