Design and realization of an inherently gain flattened Erbium doped fiber amplifier+

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Abstract: We report design and results on realization of an asymmetric co-axial dual-core fiber for an inherently gain flattened EDFA with median gains ≥ 28 dB and gain excursion within ± 2 dB across the C-band.

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1. Introduction

Erbium doped fibers have been the major driver behind the success and revolution witnessed with dense wavelength division multiplexed (DWDM) systems. The gain spectrum of a typical EDFA is however characterized with certain non-uniformity, which may induce unacceptable bit-error rate for some of the DWDM channels due to differential optical signal to noise ratio in a cascaded chain of EDFA's [1]. Various techniques to flatten gain spectrum of an EDFA require use of gain equalization filters (GEF) [2-6]. In this paper, we present first results on design and fabrication of a new coaxial dual-core gain-flattened EDF refractive index profile (RIP) without requiring a GEF and it is based on resonant coupling analogous to that in an asymmetric directional coupler.

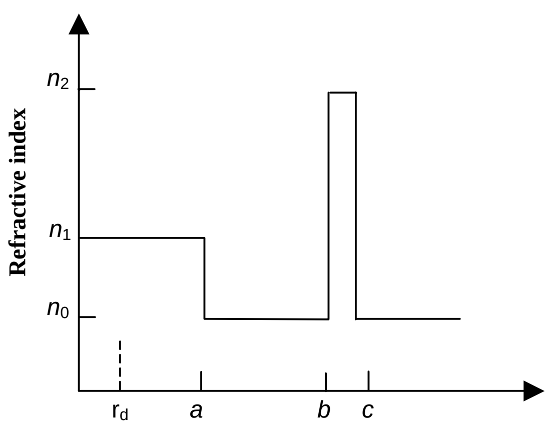

Fig. 1a)

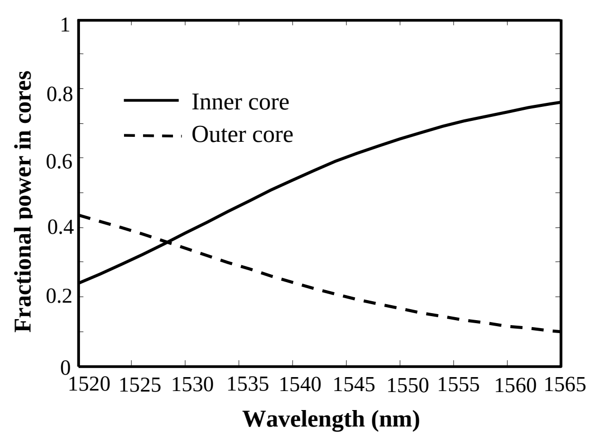

Fig. 1b)

Fig. 1 a) Schematic of the RIP of the proposed dual-core fiber; b) Fractional power within the two individual cores as a function of wavelength for a dual-core fiber (having λ_P ~ 1530 nm) that illustrates switching of guided power from outer to the inner core at wavelengths longer than λ_P within the C-band; note that some fraction of the total power of the composite fiber at any wavelength would also reside outside these cores.

2. Fiber design

Schematic diagram of the RIP of the proposed coaxial fiber design is shown in Fig. 1 a). It is assumed that the inner core is partially doped with Erbium up to a radius of r_d. The fiber parameters *a*, *b*, *c*, n_1 and n_2 were optimized such that the fundamental modes corresponding to the isolated cores are phase-matched at nearly a wavelength (λ_P) of 1530 nm. It could be seen from Fig. 1 (b) that below λ_P, more of the signal power resides in the outer core and for

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wavelengths longer than λ_P, the fractional signal power in the inner doped core becomes more than that in the outer core. Thus, these longer wavelength signals would experience larger gain compared to those at wavelengths shorter than 1530 nm, and hence the relative difference in the gain spectrum between shorter and the longer wavelengths in the C-band would reduce thereby, resulting in an effective flattening of the gain spectrum of the EDFA. The gain spectrum of this dual core EDF was modeled by using the standard three-level rate equation model [7], assuming forward pumping at 980 nm. The model also includes the wavelength dependent forward and backward traveling amplified spontaneous emission (ASE). Keeping in view fabrication constraints of the MCVD method, one set of optimized design parameters that was obtained through simulation was: dimensions r_d, a, b, c, d as 1.5, 5.25, 13, 14.8, and 62.5 all in μm, respectively; refractive indices n_0, n_1, n_2 respectively, were 1.44402, 1.45327, and 1.4617 at λ=1550 nm; Er^{+3}-concentration was chosen to be 1.75×10^{25} ions/m^3. Based on this design as a target, fabrication recipe was defined and an EDF was fabricated. The RIP of the fabricated EDF is shown in Fig. 2. The so realized RIP was close to the designed one except for small profile perturbations typical in the MCVD process. Fig. 3 shows a sample of the measured 16-ch signal gain under condition of multi-channel operation with I/P signal levels kept at –20 dBm/ch. Gain variation was found to be more than the designed one due to variations in the profile parameters. However measured signal gain variation in the wavelength range 1545 ~ 1558 nm was ≤ ± 0.3 dB, which is much less than even the designed value (± 0.8 dB). Nevertheless, it demonstrates the proof of concept of our proposed dual core coaxial EDF as a route to achieve gain flattening in EDFAs. Fabrication recipe is being farther perfected to achieve better results. We have also obtained gain flattened EDF designs following the same route for the L-band (1.57 ~ 1.61 μm), which are awaiting fabrication.

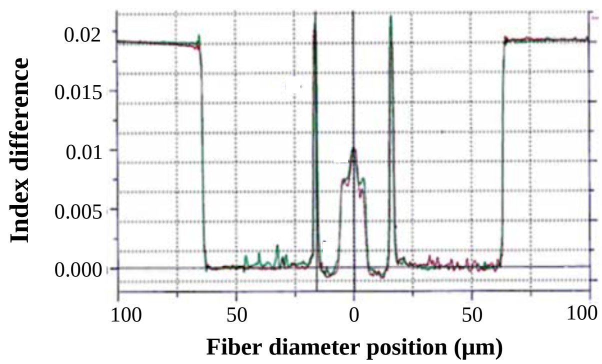

Fig. 2: RI profile of inherently gain flattened EDF (IFC-7)

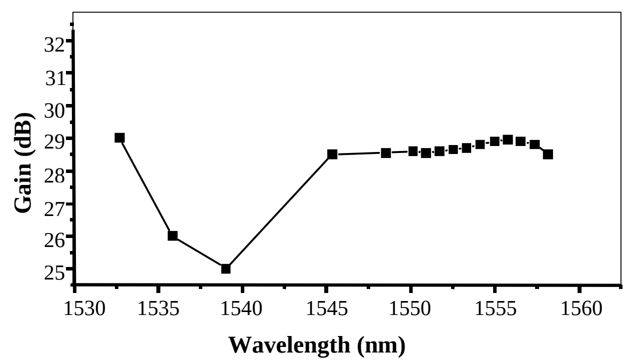

Fig. 3: The optical gain for multi-channel amplification of fiber sample IFC-7 at I/P signal level of -20dBm/ch

3. Conclusion:

We have proposed and realized a highly asymmetric dual-core coaxial EDF design, by tailoring phase resonant optical coupling between the two cores, to flatten the gain spectrum of an EDFA. Such an intrinsically gain flattened EDFA should cut down the cost on the GEF head of an EDFA in a transparent metro network scenario, which require flexibility to route/drop off signals at any node in the network.

4. References

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