S^2 Mode Content Measurement of a 7+1 to 1 Backward Pump-Signal Combiner

L. Bansal, R. Sienkowski, C. Neale, J. Mann, J. W. Nicholson
OFS Laboratories, Somerset, NJ 08873

ABSTRACT

In this work we report a -24dB LP11 mode suppression in a 7+1 to 1 Backward Pump-Signal Combiner. The mode content is measured using the S^2-Measurement technique. The high signal beam quality is attributed to a low overlap splice loss between the Tapered Fiber Bundle and the output fiber. The combiner output fiber is large mode area with a LP01 mode effective area of 584 um^2.

All-fiber Backward Pump-Signal Combiners (PSC's) play a key role in pumping fiber laser and amplifier systems enabling monolithic device structure and lower fiber nonlinearities [1]. The signal beam quality of the backward PSC is an important measure of performance as it affects both the beam quality and efficiency of the overall amplifier system. Backward PSCs in a 6+1 to 1 end pumping scheme have been demonstrated with a 5% signal loss, M^2 of 1.84 and a LP01 mode effective area of 360 um^2 [2]. Typical 6+1 to 1 PSC's can be pump-limited, so we demonstrated a power scaling forward 7+1 to 1 PSC with a 6kW power handing, pump transmission of 98% and thermal slope of 0.0037 C/W, a potential 9 kW pump power capacity [3]. The key advantage of the 7+1 to 1 PSC is that each pump arm can be pumped using standard 7 to 1 pump combiner to build a power scaling 49+1 to 1 tree architecture of combiners. To provide system level optical and thermal advantages, in this work we have focused on developing a 7+1 to1 Backward PSC.

The 7+1 to 1 backward PSC developed in this work has seven, double-clad, multimode input pump pigtails with 231 μm, 0.22 NA core and 250 μm clad, 22/400 LMA double-clad input signal fiber, and a one double-clad 34/320 output signal fiber. The PSC mode content was measured using the Spatial and Spectral (S^2) Measurement Method [4]. This measurement technique works by spatially resolving the spectral interference between light in different modes of a few-mode fiber which propagate with different group delays. Light is spatially filtered using a single mode fiber which is coupled into an OSA, the optical spectrum is then Fourier transformed to image each mode and to compute the relative power levels in each propagating mode [5]. The measurement set-up is shown in figure 1, the source is a broadband SLD with a center wavelength of 1041nm and an optical bandwidth of 80nm. A standard 6+1 to 1 PSC (PSC-IN) with a LP11 mode suppression of 34 dB (Figure 2a) is used to launch into the 7+1 to 1 PSC which is the device under test (PSC-DUT). The light from the backward PSC signal fiber (34/320um) which is at the center of the 7+1 to 1 bundle is then imaged in an image plane which is then scanned by a standard single mode fiber, as shown in figure 1. The optical spectrum is recorded at each spatial point in the image plane and is post processed to generate mode images and calculate the multipath interference (MPI) for discrete and distributed scattering into higher order modes.

Figure 2b shows the Fourier transform of the optical spectrum and post data analysis shows the presence of two modes (LP01 and LP11) propagating in the combiner 34/320um output fiber. The LP11 mode suppression was calculated to be -24dB.

In summary, we demonstrate a backward 7+1 to 1 PSC with a LP11 mode suppression of -24 dB and a large mode area of 584 um^2. The 7+1 to 1 combiner developed in this work is designed to enable power scaling of fiber lasers and amplifiers while managing fiber nonlinearities.

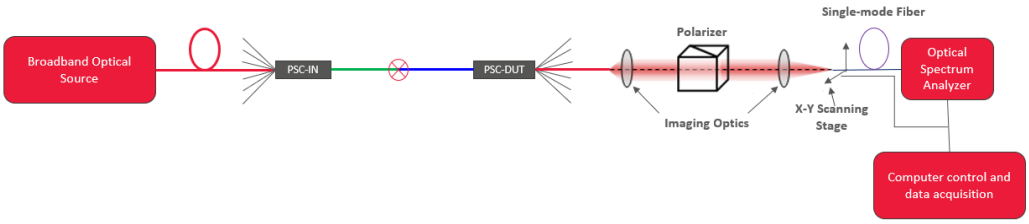
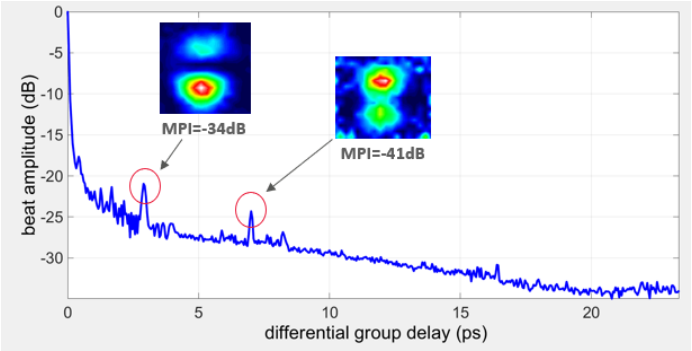
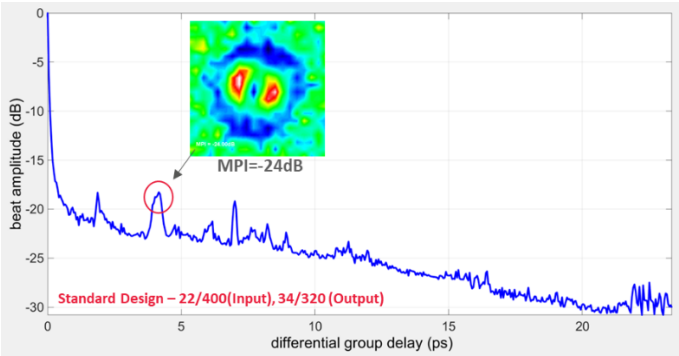


Figure1: Schematic of the S^2 measurement set-up for the 7+1 to 1 combiner.



(a)



b)

Figure 2: Fourier transform and Mode images of a) Launch 6+1 to 1 PSC-IN and b) Backward 7+1 to 1 PSC-DUT.

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