populated at the 1% level we find each interacts with the fundamental mode nearly independently, and each is suppressed as though the other modes were absent.

We note that the fundamental mode is not unique in creating a differential gain between the two polarizations of a much weaker mode. It appears that any strong mode can produce this effect on any weak mode.

6. Conclusions

In coherent beam combining a pure fundamental (LP_{01}) mode is desired from each fiber amplifier. The second mode (LP_{11}) probably poses the biggest problem because it adds variable uncorrected tilts to the beam which degrades efficiency of the combination process. This mode is also easily populated at launch by slight tilts and displacements of the amplifier fiber relative to the input beam. Only the light in LP_{11} polarized parallel to the fundamental at the output end is of real concern because the orthogonally polarized light, while it wastes a certain amount of pump power, does not interfere with beam combination.

As we have demonstrated, in a PM fiber the parallel polarized light of the non-dominant mode is substantially suppressed by gain saturation. Differential gain between the fundamental and higher order modes due to mode competition does not worsen the beam quality as is sometimes claimed, but rather helps purify the output beam. In non-PM fiber the polarizations of the fundamental and higher order mode do not evolve together, so at the fiber output the power in a higher order mode is on average nearly equal in the two polarizations, and its power is intermediate between the suppressed and enhanced levels. Here again, however, mode competition does not degrade mode purity. Only in tightly bent fiber does the mode purity degrade due to mode competition.

If greater suppression of higher order modes is required than is available from the mode competition effect, confined doping can be used. We have shown that this suppression adds with that provided by competition. However, confined doping may be incompatible with tight bending.

The overall conclusion must be that the effects of mode competition on beam quality from high power fiber amplifiers are modest, and except for tightly bent fiber are unlikely to strongly impact the beam quality. However, it is noteworthy that to the extent it does have an influence, it is usually positive, contradicting the notion of degradation due to mode competition. In any case, we have demonstrated that the effects can be modeled realistically in reasonable run times, so further exploration through modeling is straightforward.

Finally we note the well known method of bending the fiber to smaller radii than we used can be an effective way to suppress higher order modes. The differential bend loss between the fundamental and higher order modes may be sufficient to suppress higher order modes without excess loss of the fundamental [17]. Done properly, this can have a much stronger influence on beam quality than does mode competition.

#145663 - $15.00USD Received 11 Apr 2011; revised 17 May 2011; accepted 18 May 2011; published 25 May 2011