Optimal Order of Intra-Cavity Devices in Ring Cavity Fiber Lasers

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The output pulse energy is one the important characteristics of mode-locked lasers [1]. Here we quantify theoretically and through numerical modelling the impact of the order of the cavity elements on the generated pulse energy for the case of all-normal dispersion ring cavity fiber laser. We consider the fiber laser cavity composed of a saturable absorber (SA), passive and active fiber (PF and AF respectively) and an output coupler (OC). Parameters of the devices are kept the same regardless of their arrangement in the cavity.

There are six possible cavity configurations that can be obtained from the above-mentioned elements. To estimate the pulse energy at the output coupler the theory developed in [2,3] is employed. The qualitative consideration is based on the assumption that pulse energy after active fiber should be about the same in all six configurations. This is evidently not true for all lasers, but this assumption is supported in the considered schemes by comparison with direct numerical modelling. In particular, when the passive fiber is absent, we have just two possible configurations: AF-SA-OC and SA-AF-OC (the saturable absorber is followed by the active fiber and it, in turn, is followed by the output coupler). The SA losses are minimal when the SA input power is at maximum. This means that it would be beneficial to place the saturable absorber right after the active fiber.

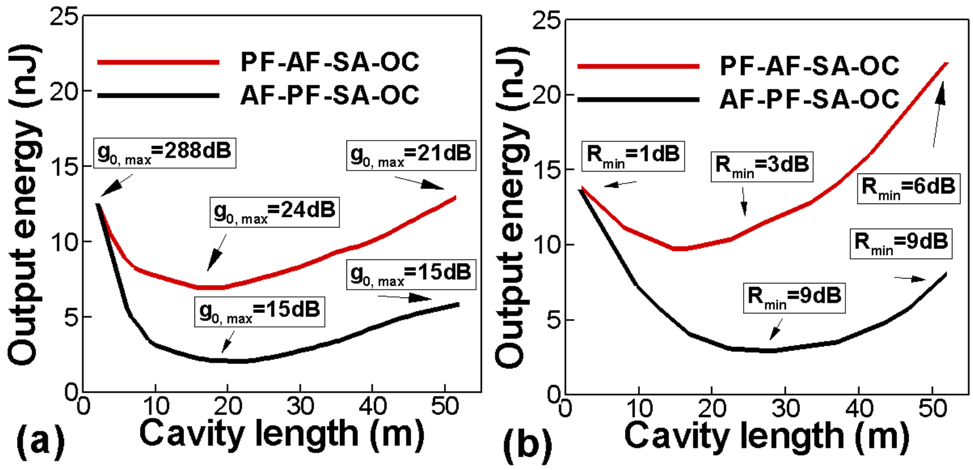

Fig. 1 Output energy values for various cavity lengths.

Figure 1a shows the output energy for various cavity lengths. To obtain these results, the maximum cavity gain ($g_{0,max}$) was found at which the stable pulse generation is still possible, and the output coupler losses were set to be 9.85 dB. Figure 1b shows the results of the output energy optimization. The optimization was performed for the cavity with the maximum gain that has been obtained previously for a given cavity length. To optimize the output energy value, the output coupler losses (R) have been varied. It can be seen from figure 1 that for the "worst" configuration the cavity losses cannot be reduced significantly and the generation is impossible if the losses are lower than 8-9 dB. On the other hand, for the "best" configuration it is possible to reduce the cavity losses by means of varying the output coupler losses and the generation is still possible if the losses are about 3 dB. Thus the generation range is significantly expanded compared to that for the "worst" case.

Given the results presented above it can be concluded that to maximize the output energy it is necessary to place the elements that have larger losses for the smaller input power immediately after the gain medium. Also the output coupler should be placed right after that element. The advantage of this optimal order increases for fiber lasers with ultra-long cavities.

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