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Control of ring lasers by means of coupled cavities

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Coupling of optical cavities offers a means of controlling the properties of one cavity (e.g., a laser) by making adjustments to another, external cavity. In this contribution we consider a unidirectional ring laser (bow-tie laser) coupled to an external ring cavity. Using different configurations we can control the out-coupling from the ring laser thereby influencing the threshold and the circulating power in the different ring cavities. This may be used to achieve the best balance between the passive losses and a nonlinear loss such as, for example, the second harmonic generation process in an optical parametric oscillator. We have found that by quickly changing the phase of the feedback loop in the external cavity it is possible to Q-switch the ring laser. Also, at certain values of the phase of the feedback in the external ring, instabilities in the total system occur and oscillations arise in the ring laser. This behavior is described by our theoretical models and confirmed experimentally. The theoretical description involves the solution of a set of transcendental nonlinear equations, one for the laser, one for the nonlinear optical process and one for the output coupling. The coupling is controlled by the transmissive properties of the coupled Fabry-Perot rings. The models of modern PC-based mathematics programs offer new possibilities for quickly and conveniently solving these equations and obtaining new information on the complex behavior of coupled nonlinear mirrors. We have specifically considered a bow-tie unidirectional ring laser coupled to an external triangular Fabry-Perot ring. At first, we couple to an empty ring with an output mirror mounted on a piezoelectric actuator. The phase of the feedback loop is such that the feedback is lost. We can then vary the phase of the feedback loop to obtain a change in the circulating power in the ring laser. By varying the position of a variable phase mirror, we can measure the effect of the variable phase on the circulating power in the ring laser. In this way, we can optimize the efficiency of the nonlinear crystal. As is well known theoretically, the effect of finding back the harmonic light in the appropriate phase is an apparent increase in the conversion efficiency of the crystal.

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