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Observation of Period Doubling in an All-Optical Resonator Containing NH_3 Gas

R. G. Harrison, W. J. Firth, C. A. Emshary, and I. A. Al-Saidi
Department of Physics, Heriot-Watt University, Riccarton, Edinburgh EH14 4AS, United Kingdom
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Two-round-trip-time modulation of the cavity field has been observed in a passive ring resonator, containing an ammonia cell, pumped by smooth 100-ns CO_2 laser pulses. The results are in excellent accord with the theory of Ikeda instability/instability in a two-level system, which is generalized to include reservoir kinetics.

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Systems exhibiting period-doubling cascades to chaotic behavior while governed by deterministic equations have attracted great interest.[1,2] Passive all-optical systems are particularly interesting here, as basically simple systems capable of exhibiting oscillation[3,4] and turbulence, but also because they can be fully quantized. Ikeda[3] showed in 1979 that an optically bistable ring resonator containing a two-level system can show a period-doubling cascade, a sufficiently strong cw input beam yielding an output oscillating at *twice* the resonator round-trip time t_R. On further increase of the input field the output period doubles to chaos. Since then, observations of these phenomena have been made in various optical systems, such as a hybrid bistable device[5] and lasers,[1,6] but the nearest approach to Ikeda's system has been a recent demonstration[7] in a fiber-optic resonator, using mode-locked excitation to avoid stimulated scattering. None of these systems are particularly simple, nor do they lend themselves to quantization. We believe that molecular gases, excited close to resonance by a CO_2 laser, have unique advantages in this field, and here we report observations of $2t_R$ oscillation (with some indications of $4t_R$) in an all-optical system very similar to Ikeda's original proposal.

A passive ring resonator was pumped by a transversely excited atmosphere (TEA) CO_2 laser pulse [10*R*(14) transition, $\lambda = 10.3\ \mu$m]. This line lies 1.23 GHz above the $aR(11)$ transition[8] of the NH_3 gas contained in a 1-m intracavity cell at pressures of 9–15 Torr, where it acts as a *homogeneously broadened* two-level system.

The arrangement is illustrated in Fig. 1. The CO_2 hybrid TEA laser/amplifier system yields smooth, single, transverse and longitudinal mode pulses of full width at half maximum ~ 100 ns [Fig. 2(a)] and peak power ~ 1 MW. The laser pulses are coupled, with use of a single-surface Ge flat, $R = 36\%$, into a 3.5-m three-element ring cavity, closed by 100% gold mirrors, containing the gas cell. The input and cavity signals were sampled by KBr beam splitters, and monitored

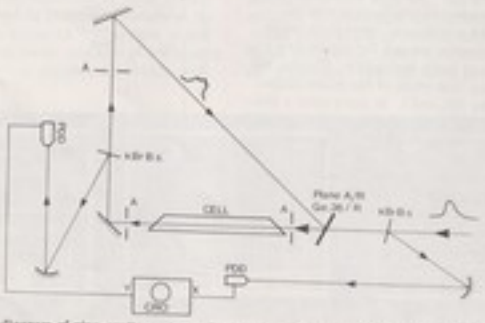

FIG. 1. Schematic diagram of ring-cavity system. B.S.: beam splitter; PDD: photon-drag detector; A/R: anti-reflection coated.