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# This Week's Citation Classic

**Siegman A E.** Unstable optical resonators for laser applications. *Proc. IEEE* **53**:277-87, 1965. [Department of Electrical Engineering, Stanford University, Stanford, CA]

**The first primitive description of resonant modes in 'unstable' optical resonators is presented. Their potential usefulness for high-power lasers is suggested. Unstable resonators are formed by two laser mirrors with divergent curvatures, so that the laser radiation walks transversely outward in the laser cavity upon repeated bounces. [The *SCI*® indicates that this paper has been cited over 100 times since 1965.]**

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"Emergence of the laser in 1960 brought rapid progress in understanding optical resonators, and the low-loss gaussian-profile modes that can be formed between two concave mirrors facing each other soon became widely used in lasers. Unfortunately, the gaussian mode in a typical stable resonator has a slender profile which does not fill the volume, and therefore does not extract all the power available from a larger diameter laser medium.

"In 1967 I was attempting to control the badly aberrated beam behavior of ruby lasers by using a very small mirror on one end of the laser rod (an idea that in retrospect was not particularly sensible). About that time I read a technical report from TRG describing the concept of 'diffractive coupling.'[1] TRG was an early laser firm, no longer in existence, attempting to develop the laser ideas put forward by Gordon Gould. This report proposed a cavity with a planar mirror on one end and a divergent mirror on the other. A plane wave coming from the flat mirror would be reflected by the divergent spherical mirror as an expanding spherical wave, and partly coupled out as an annular ring past the edges of the flat mirror. It was immediately obvious to me that this was not self-consistent. One should look instead for a pair of spherical waves bouncing back and forth with wavefront curvatures which would be self consistently reimaged at each end of the cavity. A few pages of calculation rapidly uncovered these self-consistent solutions, and developed the zero-order geometrical analysis of the unstable resonator ('unstable' because radiation walks out the side on repeated bounces, rather than being trapped as in a 'stable' resonator). I excitedly put these ideas into a letter to TRG, followed by an updated version a few days later, but never received any reply to either. Crude experiments using a ruby rod soon verified my elementary analysis.

"Following the original publication, I wrote several papers developing a more detailed understanding of unstable resonators and predicting their useful properties.[2,3,4] Other people in the US and USSR contributed important ideas that I had overlooked.[5] The detailed properties of the unstable resonator turned out to be complex and analytically rather intractable, and despite its virtues the unstable resonator did not find widespread application for a number of years. I think this was partly because of its complex properties, but even more so because of some innate suspicion of the idea of a resonant mode in an 'unstable' system. The advent of larger and higher-power lasers around 1970 brought a sharp rise in popularity of the unstable resonator, and it is now clearly the optimum choice for a wide range of different types of high-power and high-energy lasers."

1. **LaTourette J T, Jacobs J S & Rabinowitz P.** Improved laser angular brightness through diffraction coupling. *Appl. Optics* **3**:981-2. 1964.
2. **Siegman A E.** Unstable optical resonators. *Appl. Optics* **13**:353-67, 1974.
3. **Siegman A E & Arrathoon R.** Modes in unstable optical resonators and lens wave guides. *IEEE J. Quantum Electron.* QE-**3**:156-63, 1967.
4. **Siegman A E & Miller H Y.** Unstable optical resonators loss calculations using the Prony method. *Appl. Optics* **9**:2729-36. 1970.
5. **Anam'ev Y A.** Unstable resonators and their applications (review). *Sov. J Quant. Electron.* **1**:565-86, 1972.