Relaxation Oscillation of Laser Diode



Overview

Relaxation Oscillations When lasers experience disturbances like fluctuations in pump power during operation, they exhibit a phenomenon known as relaxation.

Key Takeaways

Relaxation oscillations in laser diodes are damped oscillations of the output power caused by the interplay between carrier density and photon density, typically occurring in class B lasers after a perturbation.

Mechanism

Relaxation oscillations occur when a laser diode experiences a disturbance, such as a sudden change in pump current or optical feedback. In class B lasers, which include most semiconductor laser diodes, the upper-state lifetime (carrier lifetime) is much longer than the photon lifetime in the cavity, leading to coupled oscillations between the population inversion and the optical power in the resonator. These oscillations are initially strong but gradually damp out, allowing the laser to reach a steady-state output.

Frequency of Oscillations

The relaxation oscillation frequency depends on several laser parameters: Intracavity power: Higher output power increases the oscillation frequency. Resonator losses and round-trip time: These affect the photon lifetime and the feedback dynamics. Saturation energy of the gain medium: Determines how quickly the gain responds to changes in photon density.

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Carrier lifetime: Longer carrier lifetimes reduce the oscillation frequency. Mathematically, the frequency can be derived from the linearized rate equations of the laser, which couple the photon density and carrier density dynamics.

Laser Spiking

A large-signal version of relaxation oscillations is laser spiking, which occurs when the laser is first turned on. The output emits several strong pulses before settling into a steady-state power level. This is essentially the same mechanism as relaxation oscillations but with larger amplitude.

Effects of Optical Feedback

Laser diodes are sensitive to optical feedback, which can excite or modify relaxation oscillations. In some configurations, feedback can suppress or enhance oscillations, depending on the delay time relative to the oscillation period. For example, if the product of the oscillation frequency and external-delay time equals a small integer, the laser can become insensitive to relaxation oscillations, which is useful for designing stable diode lasers.

Practical Implications

Understanding relaxation oscillations is crucial for: Optimizing laser stability: Minimizing unwanted power fluctuations. Designing high-speed modulation: The oscillation frequency sets a limit for modulation bandwidth. Mode-locking and Q-switching: Saturable absorbers or feedback can exploit these oscillations for pulsed operation.

In summary, relaxation oscillations are a fundamental dynamic behavior of laser diodes, reflecting the interaction between carriers and photons. Proper control of these oscillations is essential for stable and high-performance laser operation.

Article Content

Relaxation Oscillations

When lasers experience disturbances like fluctuations in pump power during operation, they exhibit a phenomenon known as relaxation oscillations. This behavior is common in class B lasers, where the

Relaxation Oscillation Dynamics in Semiconductor Diode Lasers With ...

We theoretically investigate the stability of a single-mode semiconductor laser with weak optical feedback in the short external-delay regime. Although the laser is, in general, very sensitive to

Relaxation Oscillation Dynamics in Semiconductor Diode Lasers With ...

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Relaxation Oscillation Dynamics in Semiconductor Diode Lasers With Optical Feedback Abstract: We theoretically investigate the stability of a single-mode semiconductor laser with weak

4.3: Stability and Relaxation Oscillations

This page examines the return of a laser system to steady state post-perturbation, emphasizing gain and power behavior via differential equations. It determines relaxation rates and eigen frequencies,

Relaxation oscillation dynamics in semiconductor diode lasers with ...

Although the laser is, in general, very sensitive to feedback-induced excitation of relaxation oscillations, we predict complete insensitivity for these oscillations when the product of oscillation frequency and

5_Relaxation oscillations

Measurement of small signal gain Measured relaxation oscillation frequency for different output couplers, for relaxation oscillations independent of output coupler Example: diode-pumped Nd:YLF laser

Laser Dynamics – spiking, relaxation oscillations, Q-switching,

Relaxation oscillations are damped oscillations of the laser''s output power that typically occur after a disturbance, such as a change in pump power. They arise from the dynamic interplay between the

Laser Relaxation Oscillations: Class B Dynamics & Stability Guide 2025

Complete guide to laser relaxation oscillations, Class B dynamics, spiking behavior, and frequency characteristics.

UFS Lecture 10: Laser Dynamics

In active Q-switching, the losses are reduced, after the laser medium is pumped for as long as the upper state lifetime. Then the loss is reduced rapidly and laser oscillation starts.

5_Relaxation oscillations

Relaxation oscillations Example: diode-pumped cw Nd:YLF laser Measurement of small signal gain

InGaN Laser Diodes-Gain, Spectra and Nonlinear Dynamics

In this era, short-wavelength laser diodes with quantum-well (QW) structures offer plenty of opportunities for improvement in laser performance and receive widespread attention. Therefore, we develop

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A simple laboratory experiment for studying the relaxation oscillations ...

This phenomenon of damped oscillations is ermed as relaxation oscillations in lasers. It restricts themodulation frequency ofdiode laser and thus puts anupper limit onthe bandwidth of systems

Relaxation Oscillations

Solid-state lasers and laser diodes often operate in this regime, showing relaxation oscillations that eventually dampen and return to a steady state. Characteristics of Relaxation Oscillations

arXiv:1405.4742v1 [physics.optics] 19 May 2014

Abstract We propose in this communication an experimental study of the relaxation os- cillations behavior in mode-locked lasers. The semiconductor self-pulsating laser diode is composed by two

High Accuracy Measurement of Relaxation Oscillation Frequency in ...

Abstract—The frequency of relaxation oscillations in a heavily damped quantum well laser, as a function of injection current, have been measured with an accuracy as good as 0.3% using a new method

Laser Dynamics – spiking, relaxation oscillations, Q-switching,

The relaxation oscillations may even become undamped, so that the steady-state solution becomes unstable, and the laser exhibits Q-switched mode locking or other kinds of Q-switching instabilities.

Basics of Semiconductor lasers

Display a stable output (with only transient relaxation oscillations). Single-mode “conventional” EELs diode lasers are class B lasers. Other class B lasers are ruby, Nd:YAG, and CO2 lasers. Because of

[1405.4742] Experimental investigation of relaxation oscillations ...

We propose in this communication an experimental study of the relaxation oscillations behavior in mode-locked lasers. The semiconductor self-pulsating laser diode is composed by two

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