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Numerical Investigation of Transient Mode-Locking Dynamics in a SESAM-Based Yb-Doped Picosecond Fiber Laser

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Abstract

This study investigates the transient mode-locking dynamics and parameter-sensitive pulse evolution in a ytterbium-doped mode-locked fiber laser under near-zero net-dispersion conditions. The influence of gain saturation energy E_s , modulation depth T_0 , saturation power P_{sat} , and non-saturable loss P_{ns} on transient pulse evolution and mode-locking buildup is comparatively analyzed using the complex Ginzburg–Landau equation. Numerical results indicate that increasing the gain saturation energy E_s weakens the gain saturation effect and prolongs the transient buildup process of stable mode locking, while simultaneously promoting intracavity energy accumulation and spectral broadening through enhanced nonlinear phase evolution. Increasing the modulation depth T_0 accelerates mode-locking initiation through enhanced nonlinear transmission contrast, whereas saturation power P_{sat} mainly affects the transient intracavity energy accumulation process during pulse evolution. Increasing the non-saturable loss P_{ns} suppresses low-intensity fluctuations during pulse buildup and contributes to faster gain–loss stabilization inside the laser cavity. Under near-zero net-dispersion conditions, stable picosecond pulse evolution with consistent spectral and temporal characteristics is numerically obtained. The present results provide useful physical insight into gain–loss interaction mechanisms and transient dissipative-soliton dynamics in ultrafast fiber lasers.

Keywords: ytterbium-doped fiber laser; passive mode-locking; SESAM; dissipative soliton; transient mode-locking dynamics; complex Ginzburg–Landau equation

1. Introduction

Ytterbium-doped passively mode-locked fiber lasers have been widely investigated due to their high efficiency, broad gain bandwidth, and compact all-fiber configuration [1,2]. Extensive studies have focused on cavity design, mode-locking mechanisms, and pulse generation, enabling stable picosecond and femtosecond operation through various dispersion-management strategies [3]. Among them, semiconductor saturable absorber mirrors (SESAMs) combined with chirped fiber Bragg gratings (CFBGs) have become a standard platform for dispersion control and stable mode locking [4].

Although emerging artificial saturable absorbers such as graphene and MXene have been widely explored, SESAMs remain highly relevant due to their well-defined modulation response, high damage threshold, and long-term stability [5,6]. The fundamental operation principles and design methodologies of SESAMs for ultrafast lasers were systematically established in early pioneering works [7–9], forming a mature theoretical basis for pulse



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shaping and mode-locking stabilization [10,11]. In addition, their predictable nonlinear response makes SESAMs particularly suitable for numerical investigations of intrinsic pulse formation dynamics. The underlying physics of SESAM-based mode locking has been extensively studied, and such systems enable stable pulse generation through the interplay of dispersion, nonlinearity, gain saturation, and saturable absorption [12].

From a physical perspective, pulse evolution in mode-locked fiber lasers is governed by the balance between dispersion and nonlinearity, which determines the formation dynamics of dissipative solitons [13,14]. Because this balance is strongly dependent on the dispersion regime, transient dynamics observed in anomalous- and all-normal-dispersion systems cannot be directly extended to near-zero-dispersion operation without further verification. Consequently, the parameter sensitivity of pulse buildup dynamics may differ under near-zero-dispersion conditions. To date, a unified multi-parameter comparative framework that simultaneously considers transient pulse buildup and steady-state characteristics in SESAM-based near-zero-dispersion fiber lasers has not yet been well established.

Most existing studies on transient mode-locking dynamics have focused on anomalous- or all-normal-dispersion fiber lasers [15–17], where both buildup dynamics and steady-state properties exhibit strong parameter sensitivity [18,19]. In contrast, representative studies on near-zero-dispersion SESAM fiber lasers have mainly focused on steady-state operation and long-term stability, whereas transient pulse buildup dynamics and their dependence on key cavity parameters were not systematically examined in these studies [20,21].

In this work, transient mode-locking dynamics in a SESAM-based Yb-doped fiber laser operating under near-zero net-dispersion conditions are numerically investigated using the complex Ginzburg–Landau equation. The effects of four key parameters, namely gain saturation energy, modulation depth, saturation power, and non-saturable loss, are systematically compared in terms of both pulse buildup dynamics and steady-state characteristics. The results provide additional insight into parameter-dependent pulse evolution and the formation of stable mode locking in near-zero-dispersion fiber lasers.

2. Numerical Model and Simulation Setup

2.1. Numerical Model

The pulse propagation dynamics in the YDF and SMF sections are described using the complex Ginzburg–Landau equation (CGLE) [22,23], which is commonly employed for modeling pulse evolution in passively mode-locked fiber lasers [24]:

$$\frac{\partial u}{\partial z} = -\frac{i}{2}\beta_2 \frac{\partial^2 u}{\partial t^2} + i\gamma|u|^2u + \frac{g}{2}u \quad (1)$$

where β_2 is the group-velocity dispersion coefficient, γ is the nonlinear coefficient, g denotes the gain coefficient, and $u(z,t)$ represents the slowly varying pulse envelope, where t is the retarded time and z is the propagation distance.

The transmission function of the saturable absorber (SA) is expressed as [7]:

$$T = 1 - \frac{T_0}{1 + |u|^2/P_{sat}} - P_{ns} \quad (2)$$

where T_0 is the modulation depth, P_{ns} represents the non-saturable loss, and P_{sat} is the saturation power.

The initial signal is represented by a Gaussian pulse function:

$$u_x = 1 \times 10^{-9} \cdot \exp\left(-0.5\left(\frac{t}{t_0}\right)^2\right) \quad (3)$$

where u_x denotes the initial optical field amplitude, t is the retarded time coordinate, and t_0 is the initial pulse-width parameter.

2.2. Numerical Implementation

Figure 1 shows the schematic configuration of the ytterbium-doped fiber laser. The cavity consists of a semiconductor saturable absorber mirror (SESAM), an ytterbium-doped fiber (YDF) segment, a wavelength division multiplexer (WDM), a pump source, a chirped fiber Bragg grating (CFBG), and single-mode fibers (SMFs). Pump power is coupled into the cavity through the WDM. The YDF provides optical gain, while the SESAM acts as the passive mode-locking element. The pulse characteristics are monitored after the CFBG section throughout the simulation. The cavity propagation path is defined as: 0.6 m YDF $\rightarrow$ 1.25 m SMF1 $\rightarrow$ SESAM $\rightarrow$ 1.25 m SMF1 $\rightarrow$ 0.6 m YDF $\rightarrow$ 1.25 m SMF2 $\rightarrow$ CFBG $\rightarrow$ 1.25 m SMF2.

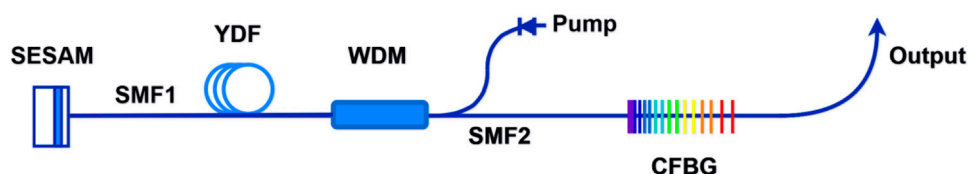


Figure 1. Schematic configuration of the simulated ytterbium-doped fiber laser cavity. SESAM: semiconductor saturable absorber mirror; SMF: single-mode fiber; YDF: ytterbium-doped fiber; WDM: wavelength division multiplexer; Pump: Pump Source; CFBG: chirped fiber Bragg grating.

The key simulation parameters we used are followed: For SMF, $L_{\text{SMF1}} = L_{\text{SMF2}} = 1.25$ m, $\beta_{2,\text{SMF}} = 24 \times 10^{-27}$ s²/m, $\gamma_{\text{SMF}} = 3.5 \times 10^{-3}$ W⁻¹m⁻¹. For YDF, $g_0 = 250$ dB/m, $E_{\text{sat}} = 30$ pJ, $\beta_{2,\text{YDF}} = 24 \times 10^{-27}$ s²/m, $\gamma_{\text{YDF}} = 3.5 \times 10^{-3}$ W⁻¹m⁻¹, $L_{\text{YDF}} = 0.6$ m. For CFBG, $\beta_{2,\text{CFBG}} = -0.25 \times 10^{-24}$ s²/m.

Dispersion management is realized by balancing the positive dispersion of SMF segments against the negative dispersion from the CFBG [22], which helps maintain stable pulse operation inside the cavity. The gain saturation (E_s), modulation depth (T_0), saturation power (P_{sat}) and non-saturable loss (P_{ns}) are treated as tunable parameters to explore their effects on pulse evolution, spectral features and mode-locking behavior.

2.3. Limitations of the Numerical Model

It should be noted that the present simulations are based on an idealized cavity model, and deviations between numerical results and practical laser systems mainly arise from two categories of factors.

First, additional intracavity losses originating from fiber splices, component insertion losses, and fabrication tolerances will introduce deviations in the absolute values of steady-state pulse energy, pulse duration, and spectral bandwidth. In general, increased losses reduce the net gain of the cavity, leading to lower steady-state pulse energy and a slight broadening of the pulse duration, while the overall spectral profile remains qualitatively unchanged. From a dynamical perspective, these additional losses moderately accelerate the intracavity gain–loss equilibration process, thereby reducing the number of cavity roundtrips required for mode-locking stabilization. Importantly, such effects primarily modify the timescale of pulse formation, while the relative sensitivity ordering among the investigated parameters remains unchanged.

Second, higher-order dispersion, higher-order nonlinear effects, and other experimental imperfections not included in the present model may lead to deviations from an ideal sech^2 pulse profile. These effects mainly affect fine temporal and spectral structures, but do

not alter the fundamental balance among dispersion, nonlinearity, gain saturation, and saturable absorption that governs dissipative soliton formation and mode-locking dynamics.

In addition, the present simulations are seeded with a deterministic Gaussian pulse rather than quantum noise. While this simplifies the analysis of intrinsic dynamics, it may affect the quantitative details of the initial buildup stage in real lasers, where the mode-locking is initiated from ASE fluctuations.

From the perspective of transient dynamics, these non-idealities act primarily as perturbations to the intracavity energy evolution, rather than modifying the underlying mechanism of pulse buildup. Therefore, while quantitative values such as pulse energy and buildup time may vary in experiments, the key conclusions of this work—namely, the strong parameter dependence of transient buildup and the relatively weak influence on steady-state characteristics—are expected to remain robust in typical SESAM-based Yb-doped picosecond fiber lasers. In particular, the ranking of parameter sensitivity across E_s , T_0 , P_{sat} , and P_{ns} is preserved under realistic perturbations, ensuring the validity of the comparative trends reported in this study.

3. Results and Discussion

3.1. Influence of Gain Saturation Energy (E_s) on Mode-Locking Dynamics

Using the CGLE-based numerical model and the simulated ytterbium-doped fiber laser cavity illustrated in Figure 1, we first obtained stable mode-locked pulse evolution under the baseline parameters: $T_0 = 0.3$, $E_s = 30$ pJ, $P_{\text{sat}} = 30$ W, and $P_{\text{ns}} = 0.4$.

Figure 2 shows the pulse evolution dynamics under these baseline conditions. Figure 2a illustrates the temporal pulse evolution during cavity roundtrips, where a stable pulse profile gradually forms after approximately 50 roundtrips. Figure 2c presents the steady-state temporal pulse profile at the 300th roundtrip, showing a near-sech²-shaped pulse envelope with a full width at half maximum (FWHM) of approximately 0.96 ps. Figure 2b shows the corresponding spectral evolution during cavity roundtrips, where gradual spectral stabilization and broadening can be observed as the pulse evolves toward a steady operating state. Notably, the secondary peaks appearing in the early evolution stage are transient intermediate states during mode-locking buildup, arising from the simultaneous amplification of multiple weak seed components under initial gain. As roundtrips increase, the dominant pulse suppresses these competing components through combined action of gain saturation and the intensity discrimination provided by the SESAM, finally forming a stable single-pulse mode-locked state. Figure 2d shows the steady-state optical spectrum at the 300th roundtrip, exhibiting a spectral FWHM of approximately 3.57 nm with stable characteristics throughout the evolution process.

The formation of stable pulse evolution is associated with the dynamic interplay among dispersion, nonlinear phase accumulation, and gain saturation effects within the laser cavity [13,14]. This operating condition in the near-zero-dispersion regime serves as the baseline for all subsequent parameter investigations.

To investigate the influence of gain saturation energy on transient mode-locking dynamics, E_s was varied from 10 pJ to 50 pJ while keeping all other parameters fixed at the baseline values defined above. Figure 3a shows the temporal evolution of the pulse during cavity roundtrips for different E_s values. As E_s increases from 10 pJ to 50 pJ, the number of roundtrips required to reach a stable mode-locked state increases from 54 to 224, indicating that higher gain saturation energy prolongs the pulse buildup process. This behavior may be associated with the ability of the gain medium to sustain higher intracavity energy before gain saturation sets in.

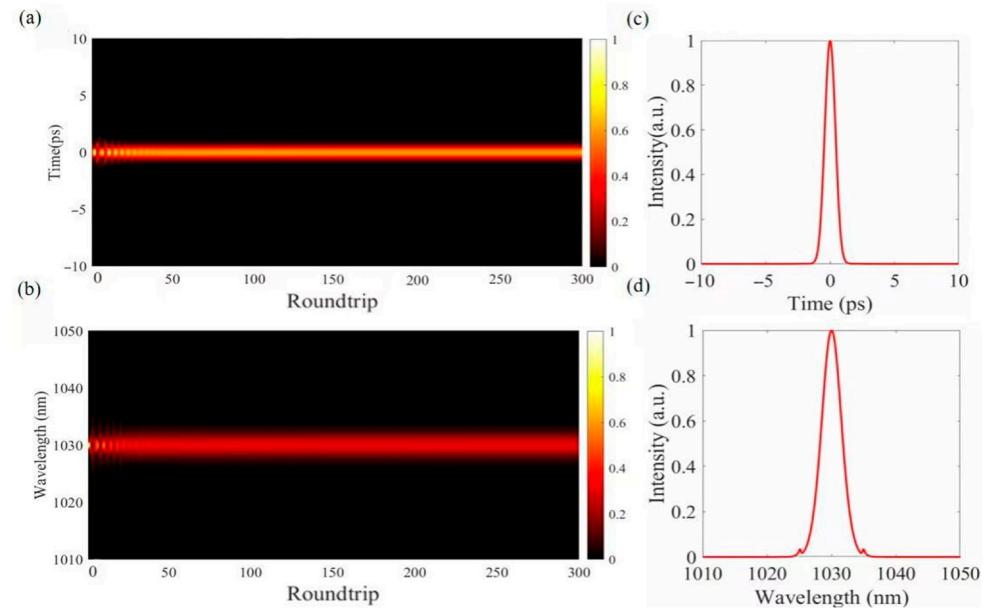


Figure 2. Simulated pulse evolution dynamics in the ytterbium-doped fiber laser cavity: (a) temporal evolution during cavity roundtrips; (b) spectral evolution during cavity roundtrips; (c) steady-state temporal pulse profile; and (d) steady-state optical spectrum.

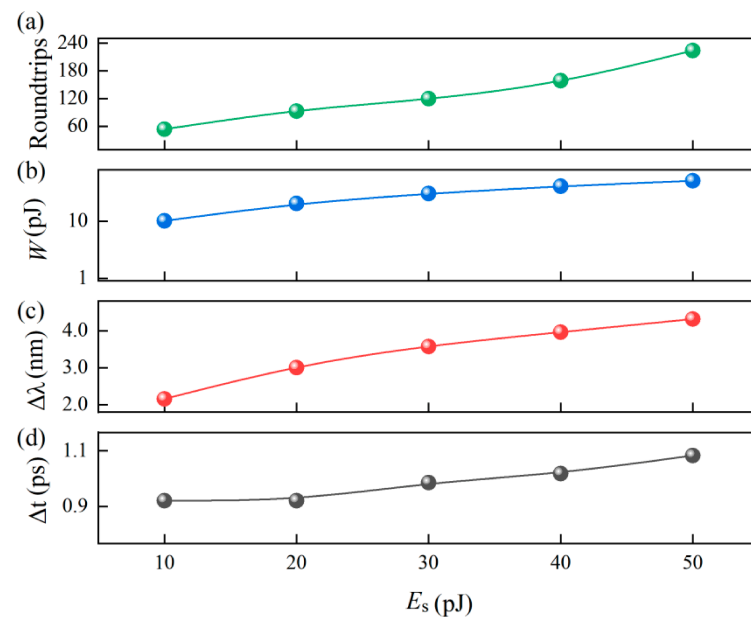


Figure 3. Influence of gain saturation energy (E_s) on (a) mode-locking stabilization roundtrips, (b) pulse energy, (c) spectral bandwidth, and (d) pulse duration.

Figure 3b presents the evolution of pulse energy. The steady-state pulse energy increases slightly with E_s , ranging from approximately 30.2 pJ ($E_s = 10$ pJ) to 30.9 pJ ($E_s = 50$ pJ), corresponding to a relative variation of about 2.3%. The gradual rise in intra-cavity energy during the early buildup stage reflects the influence of gain saturation on transient dynamics.

Figure 3c shows the spectral evolution. The spectral bandwidth exhibits mild broadening during the transient buildup process, with steady-state FWHM varying from 3.50 nm to 3.57 nm. This relatively small spectral variation may be related to the balance between nonlinear phase evolution and the near-zero net-dispersion condition of the cavity.

Figure 3d presents the temporal pulse width at steady state. Increasing E_s slightly broadens the pulse, with FWHM increasing from 0.95 ps to 0.97 ps. The effect on pulse width is modest, indicating that E_s mainly affects the buildup dynamics rather than the steady-state pulse characteristics.

These results indicate that gain saturation energy primarily modulates the rate of pulse buildup, with only minor effects on the final steady-state pulse characteristics under near-zero-dispersion conditions. This decoupled sensitivity between buildup dynamics and steady-state performance reflects a characteristic feature of near-zero-dispersion operation.

3.2. Influence of Modulation Depth (T_0) on Pulse Buildup Dynamics and Steady-State Characteristics

To investigate the influence of the saturable absorber modulation depth (T_0) on transient mode-locking dynamics, T_0 was varied from 0.2 to 0.5 while keeping all other parameters fixed at the baseline values defined in Section 3.1. Figure 4a shows the temporal evolution of the pulse during cavity roundtrips for different T_0 values. As T_0 increases from 0.2 to 0.5, the number of roundtrips required to reach stable mode locking decreases from 119 to 39. This behavior reflects the stronger amplitude discrimination provided by the SESAM at larger T_0 : the transmission difference between high-intensity pulse components and low-intensity background fluctuations becomes more pronounced, which accelerates the suppression of noise components and allows the main pulse to dominate the intracavity energy distribution within fewer roundtrips.

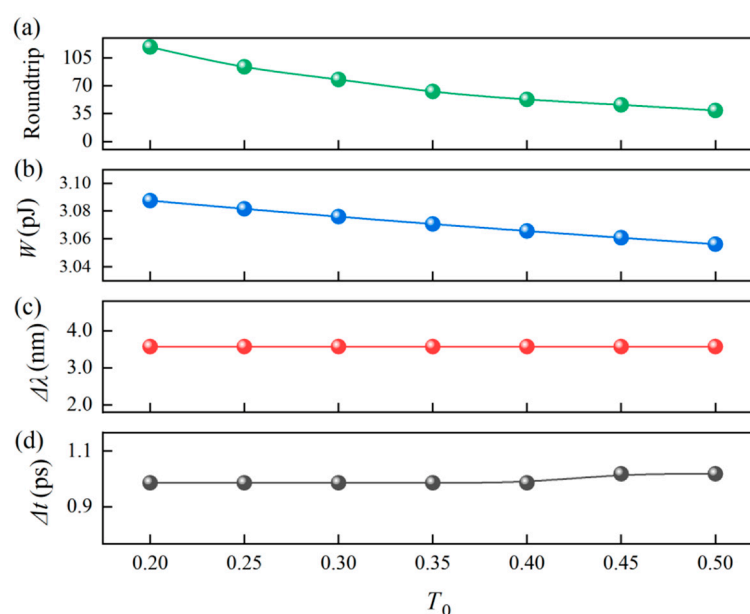


Figure 4. Influence of modulation depth (T_0) on (a) mode-locking stabilization roundtrips, (b) pulse energy, (c) spectral bandwidth, and (d) pulse duration.

Similar tendencies have been reported in previous studies of mode-locked fiber lasers [15–17], and the present results show that comparable behavior can also be observed under near-zero-dispersion conditions.

Figure 4b shows the evolution of pulse energy with varying T_0 . During the early buildup stage, a larger T_0 accelerates the rise in intracavity pulse energy by reducing losses experienced by the growing pulse due to enhanced saturable absorption. At steady state, the pulse energy increases slightly from 30.4 pJ ($T_0 = 0.2$) to 30.7 pJ ($T_0 = 0.5$), corresponding to a relative variation of less than 1%. This weak dependence may be related to the balance

between gain saturation and intracavity dispersion under near-zero-dispersion conditions, which limits further energy accumulation.

Figure 4c presents the corresponding spectral evolution during cavity roundtrips. The spectral width gradually broadens as the pulse evolves toward the steady state, with the steady-state spectral bandwidth increasing slightly from 3.48 nm ($T_0 = 0.2$) to 3.62 nm ($T_0 = 0.5$). This weak dependence suggests that T_0 mainly affects the rate of pulse buildup rather than the spectral characteristics of the steady-state pulse. The spectral broadening is moderated by the near-zero net-dispersion condition, leading to only a slight increase in spectral bandwidth over the investigated T_0 range.

Figure 4d shows the temporal pulse width at steady state. Increasing T_0 from 0.2 to 0.5 reduces the pulse width slightly from 0.98 ps to 0.94 ps, corresponding to a relative variation of approximately 4%. Such a small change confirms that T_0 has only a limited influence on steady-state pulse shaping, consistent with the general operational characteristics of SESAM mode-locking. The slight pulse shortening observed at higher T_0 may be associated with the stronger intensity discrimination provided by the saturable absorber. This weak dependence suggests that the steady-state pulse characteristics are relatively insensitive to T_0 under the near-zero-dispersion conditions considered here.

Overall, modulation depth exerts a stronger influence on the speed of mode-locking initiation than on steady-state pulse properties. These observations provide insight into how SESAM amplitude discrimination shapes transient pulse evolution, suggesting that modulation depth primarily governs transient buildup dynamics rather than steady-state pulse shaping in near-zero-dispersion cavities.

3.3. Influence of Saturation Power (P_{sat}) on Transient Mode-Locking Dynamics

To examine the effect of the saturable absorber saturation power (P_{sat}) on transient mode-locking dynamics, P_{sat} was varied from 10 W to 50 W while keeping all other parameters fixed at the baseline values defined in Section 3.1. Figure 5a shows the temporal evolution of the pulse during cavity roundtrips for different P_{sat} values. As P_{sat} increases from 10 W to 50 W, the number of roundtrips required for stable mode locking decreases moderately from 76 to 54. Figure 5b presents the evolution of pulse energy. The steady-state pulse energy decreases slightly from 30.96 pJ to 30.59 pJ, corresponding to a relative variation of approximately 1.2%. Figure 5c shows the corresponding spectral evolution. The steady-state spectral bandwidth remains nearly constant across the investigated P_{sat} range, with only minor differences observed during the transient buildup stage. Figure 5d presents the temporal pulse width at steady state. The temporal pulse width is almost unaffected by P_{sat} , indicating that P_{sat} mainly affects the transient buildup process rather than the steady-state pulse characteristics.

The observed variation in pulse buildup time may be associated with differences in the nonlinear transmission characteristics of the saturable absorber. Changing P_{sat} modifies the intensity required to reach saturation and therefore affects the transient energy evolution during pulse formation. This dependence of pulse buildup time on saturation power is consistent with general SESAM mode-locking theory [7,10], and is confirmed here for the near-zero-dispersion regime. This insensitivity of steady-state characteristics is likely related to the balanced dispersion–nonlinearity interaction in the near-zero-dispersion regime, which stabilizes the pulse profile against variations in absorber saturation power.

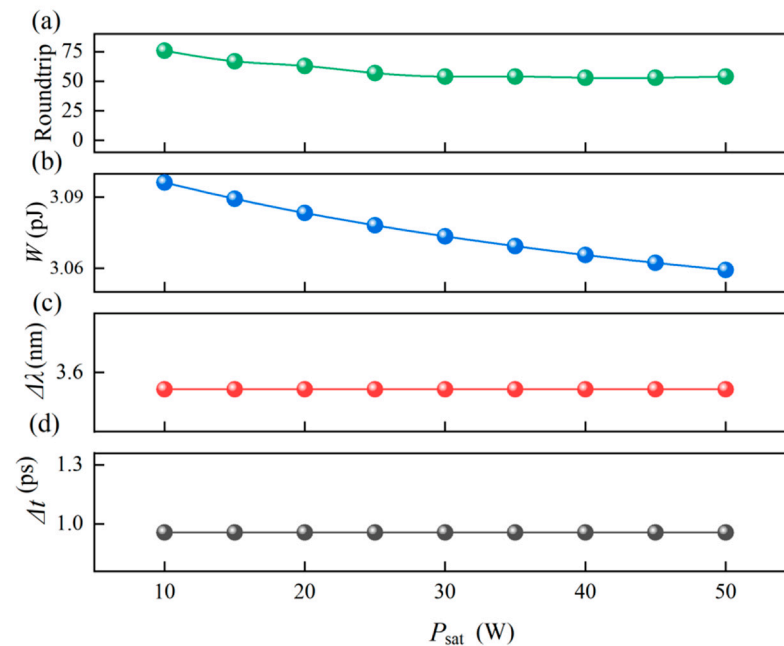


Figure 5. Influence of saturation power (P_{sat}) on (a) the number of roundtrips required for stable mode-locking, (b) pulse energy, (c) spectral bandwidth, and (d) pulse duration.

Within the investigated parameter range, saturation power affects the transient intracavity energy accumulation process, while its impact on steady-state pulse characteristics remains negligible. This result highlights the role of absorber saturation dynamics in near-zero-dispersion cavities, where steady-state pulse profiles exhibit weak sensitivity to variations in saturation power.

3.4. Influence of Non-Saturable Loss (P_{ns}) on Transient Mode-Locking Dynamics

To investigate the effect of non-saturable loss (P_{ns}) on transient mode-locking dynamics, P_{ns} was varied from 0.1 to 0.45 while keeping all other parameters fixed at the baseline values defined in Section 3.1. Figure 6a shows the temporal evolution of the pulse during cavity roundtrips for different P_{ns} values. As P_{ns} increases from 0.1 to 0.45, the number of roundtrips required for stable mode locking decreases from approximately 160 to 60. Figure 6b presents the evolution of pulse energy. The steady-state pulse energy decreases slightly from 33.4 pJ to 30.4 pJ, corresponding to a relative variation of approximately 9%. Figure 6c shows the corresponding spectral evolution. The steady-state spectral bandwidth exhibits only minor changes over the investigated P_{ns} range. Figure 6d presents the temporal pulse width at steady state. The temporal pulse width remains nearly unchanged, indicating that P_{ns} mainly affects the transient buildup process rather than the steady-state pulse characteristics.

The observed variation in pulse buildup time may be associated with changes in the intracavity loss balance introduced by different P_{ns} values. Changing P_{ns} modifies the overall intracavity loss, which may contribute to differences in transient energy evolution during pulse formation. The accelerating effect of non-saturable loss on mode-locking stabilization has been noted in prior theoretical studies [15,16], and is observed here under near-zero-dispersion conditions. The robust steady-state performance observed here indicates that the near-zero-dispersion regime effectively buffers the pulse against changes in intracavity non-saturable loss.

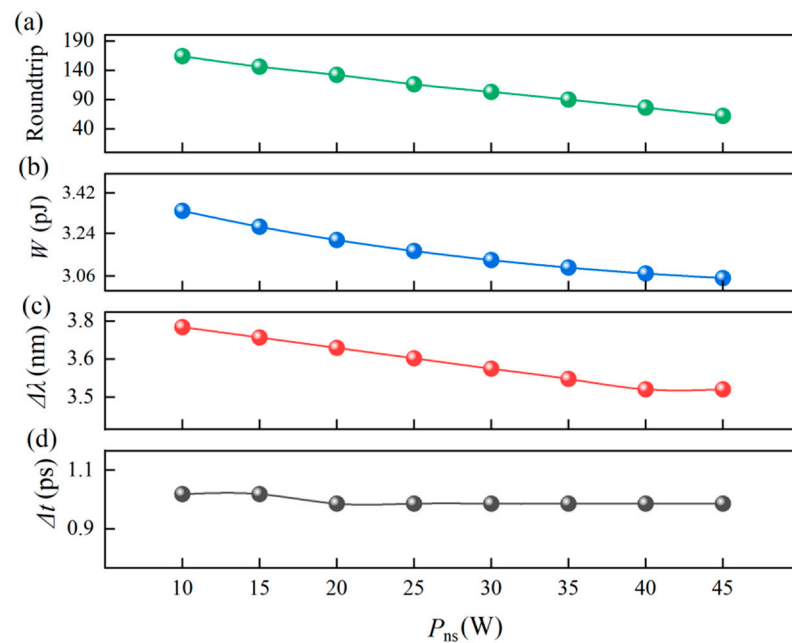


Figure 6. Influence of non-saturable loss (P_{ns}) on (a) the number of roundtrips required for stable mode-locking, (b) pulse energy, (c) spectral bandwidth, and (d) pulse duration.

These results show that non-saturable loss mainly accelerates the stabilization of the intracavity gain–loss balance, with limited influence on final steady-state pulse parameters. This behavior indicates that non-saturable loss primarily modulates pulse stabilization dynamics in near-zero-dispersion cavities, while leaving steady-state characteristics largely unaffected.

3.5. General Discussion

A consistent trend emerges across all four investigated parameters: each key gain or saturable absorber parameter exerts a marked influence on the transient pulse buildup dynamics, yet exerts only a limited impact on the final steady-state pulse characteristics. Specifically, increasing the gain saturation energy E_s prolongs the number of roundtrips required to achieve stable mode locking, whereas increasing the modulation depth T_0 , saturation power P_{sat} , or non-saturable loss P_{ns} accelerates the stabilization process. Within the examined parameter ranges, the maximum relative variation in steady-state pulse energy remains below 10%, while the variations in spectral bandwidth and pulse duration are even smaller. This clear decoupling between transient sensitivity and steady-state robustness constitutes a defining feature of the near-zero-dispersion regime.

This behavior contrasts sharply with previous studies on anomalous-dispersion [15,16] and all-normal-dispersion cavities [18,19], where steady-state pulse characteristics typically exhibit pronounced sensitivity to variations in gain and absorber parameters. In near-zero-dispersion cavities, however, the near-balance between dispersion and nonlinearity plays a stabilizing role: it anchors the final dissipative soliton state against moderate parameter fluctuations, while leaving the transient gain–loss equilibration process highly responsive to parameter tuning. Such regime-dependent behavior underscores the critical role of dispersion management in shaping both the transient evolution and the steady-state attractor of mode-locked fiber lasers, and it contributes to a more comprehensive understanding of dissipative soliton formation mechanisms [13,14].

From a practical perspective, these results offer clear engineering guidance. The parameter-dependent buildup dynamics provide quantitative references for SESAM selection and gain matching in real laser construction, enabling faster and more reliable

self-starting mode locking. Meanwhile, the robust steady-state performance observed under near-zero net dispersion implies a high tolerance to device fabrication tolerances, component insertion losses, and splicing variations—factors that often complicate practical laser implementation. This distinct operational characteristic complements the existing empirical framework, which has been largely established for anomalous- and all-normal-dispersion systems, and provides targeted insights for the design and optimization of near-zero-dispersion picosecond fiber lasers.

Quantitatively, the present results complement earlier steady-state investigations of near-zero-dispersion SESAM fiber lasers [20,21], which primarily addressed stable operation regimes without systematically examining multi-parameter transient pulse buildup dynamics. The observed weak sensitivity of steady-state pulse parameters is also consistent with previous experimental and numerical studies on SESAM-based Yb-doped fiber lasers [25,26]. Within the parameter space explored here ($E_s = 10\text{--}50$ pJ, $T_0 = 0.2\text{--}0.5$, $P_{\text{sat}} = 10\text{--}50$ W, $P_{\text{ns}} = 0.1\text{--}0.45$), the parametric trends in transient dynamics remain consistent: a shorter buildup time correlates with lower E_s , while higher T_0 , P_{sat} , and P_{ns} tend to accelerate the establishment of stable mode locking. In contrast, steady-state pulse characteristics remain comparatively insensitive across the entire investigated range.

Based on these observed trends rather than global optimization, a representative parameter region associated with faster transient response can be identified as $E_s \approx 10\text{--}20$ pJ, $T_0 \approx 0.4\text{--}0.5$, $P_{\text{sat}} \approx 30\text{--}50$ W, and $P_{\text{ns}} \approx 0.3\text{--}0.45$. Relative to the baseline configuration ($E_s = 30$ pJ, $T_0 = 0.3$, $P_{\text{sat}} = 30$ W, $P_{\text{ns}} = 0.4$), the mode-locking buildup time can be reduced by up to approximately 60% under the representative cases studied here, while the variations in steady-state pulse energy and spectral bandwidth remain within 10%. It should be emphasized that these values represent trend-consistent parameter selections derived from numerical simulations and should be interpreted as qualitative guidance for parameter tuning in SESAM-based near-zero-dispersion fiber lasers, rather than as an absolute optimum.

4. Conclusions

This study numerically investigated the transient mode-locking dynamics of a SESAM-based Yb-doped picosecond fiber laser operating in the near-zero-dispersion regime using the complex Ginzburg–Landau equation. The influence of key gain and saturable absorber parameters on pulse formation dynamics was systematically analyzed. The results indicate that laser parameters primarily affect the transient buildup process, while steady-state pulse characteristics remain comparatively stable, revealing a pronounced decoupling between transient and steady-state behaviors in near-zero-dispersion cavities. These results provide a physical reference for understanding parameter-dependent transient dynamics in SESAM-based fiber lasers under near-zero-dispersion conditions.

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Data Availability Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest: The authors declare no conflicts of interest.

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