



Spatiotemporal stabilization of PT-symmetric BAS Lasers

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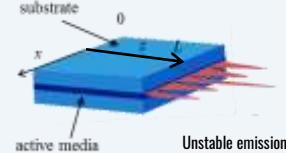
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Abstract

We propose a feasible and compact scheme to control and stabilize the spatiotemporal dynamics of Broad Area Semiconductor (BAS) lasers applying a local PT-symmetric potential [1] to enhance and localize light into a narrow, stable and bright emitted beam. The laser pump modulation, with a central symmetry axis, induces in-phase gain and refractive index modulations due to the Henry factor, which are spatially dephased to obtain local PT-symmetry by an appropriate modification of the index profile [2]. The optimized performance is found by an exhaustive exploration of the modulation parameters, achieving a significant improvement in terms of intensity enhancement, beam concentration and temporal stability [3]. This approach produces a two-fold benefit: light localization into a narrow beam emission and the control over the spatial and temporal dynamics improving the laser stability [4].

Motivation

BAS Laser scheme

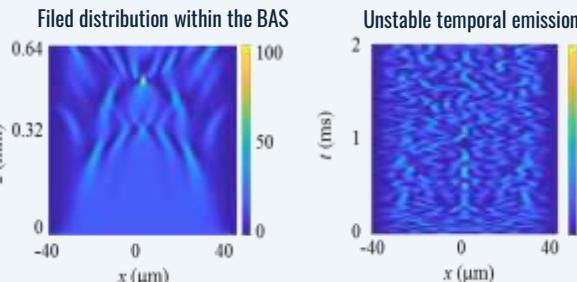


Model

$$\frac{\partial A}{\partial z} = \frac{i}{2k_0 n} \frac{\partial^2 A}{\partial x^2} + s[(1-ih)N - (1+\alpha)A + i\Delta n(x)k_0]$$

$$\frac{\partial N}{\partial t} = \gamma(-N - (N-1)|A|^2 + p_0 + \Delta p(x) + DV^2N)$$

Unmodulated BAS numerical integration

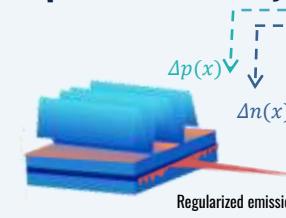


BAS lasers drawbacks

spatially inhomogeneous
temporally unstable
poor beam quality

Need for a solution to obtain a
spatially regularized
temporally stabilized
bright emission

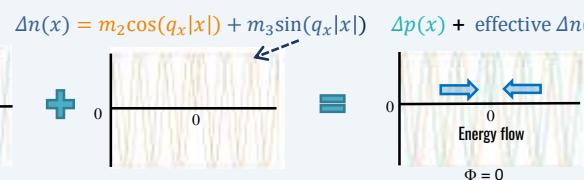
Proposal: Local PT-Symmetry



Pump and Refractive index modulations ($\Phi = 0$)

$$\Delta p(x) = m_1 \sin(q_x |x|)$$

$$\Delta n(x) = m_2 \cos(q_x |x|) + m_3 \sin(q_x |x|)$$



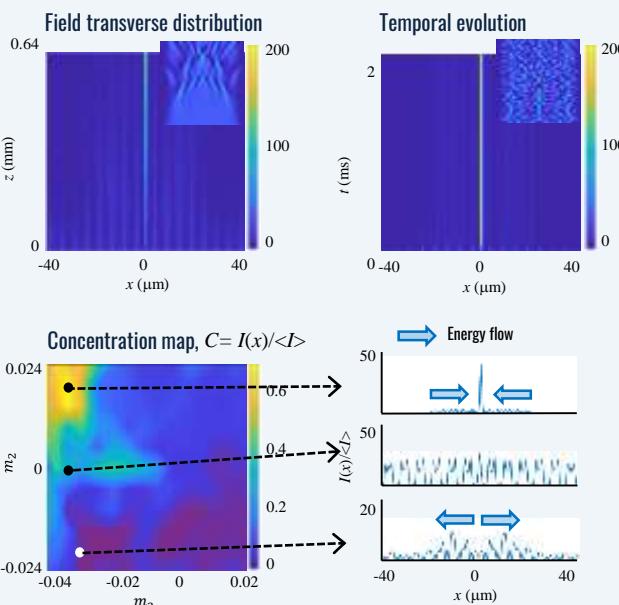
General pump and effective refractive index modulations

$$\Delta p(x) = m_1 \cos(q_x |x| + \Phi)$$

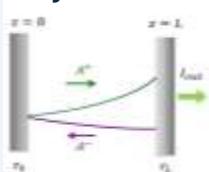
$$\Delta n(x) = m_2 \sin(q_x |x| + \Phi) + m_3 \cos(q_x |x| + \Phi)$$

Results

Amplifier



Boundary conditions for the Laser

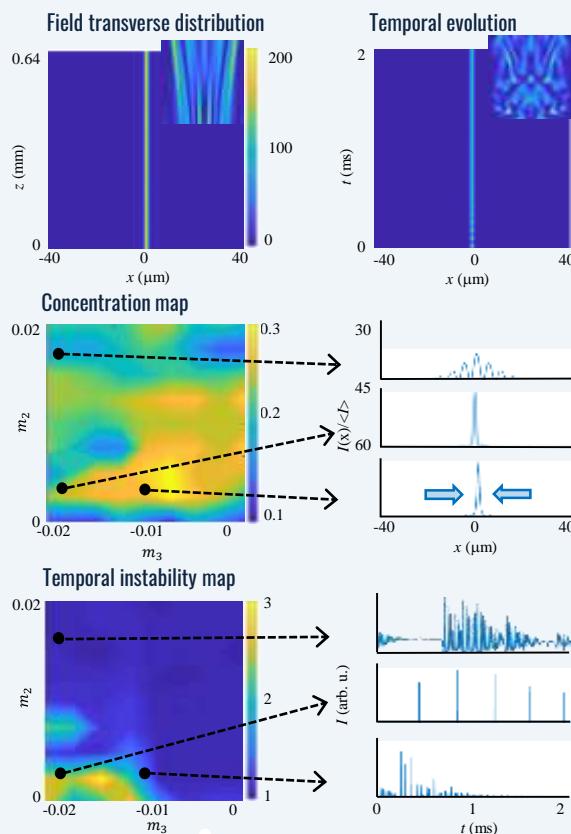


$$A(x, z, t) = A^+(x, z, t)e^{-ik_0 z} + A^-(x, z, t)e^{ik_0 z}$$

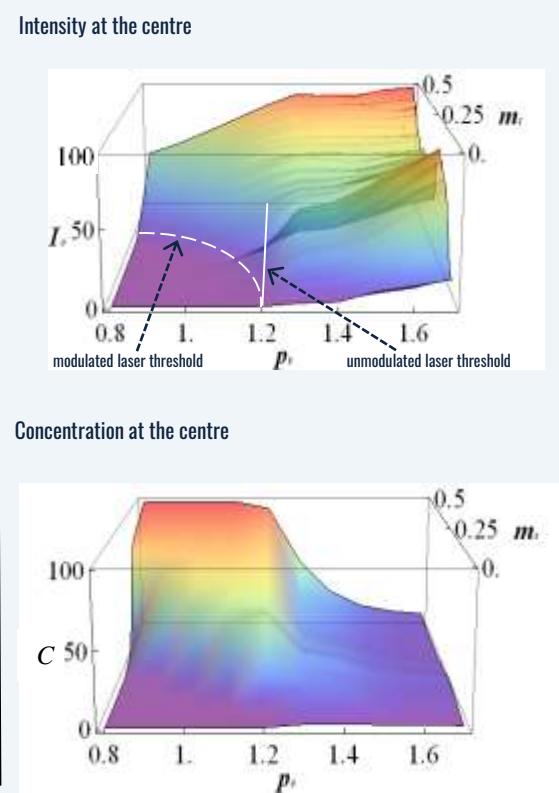
$$A^+(x, z=L, t) = r_L A^-(x, z=L, t)$$

$$A^-(x, z=0, t) = r_0 A^+(x, z=0, t)$$

Laser $r_0=0.99$; $r_L=0.9$



Laser $r_0=0.99$; $r_L=0.04$



Conclusions

- We impose local PT-symmetric potentials to tailor and control the complex spatial dynamics of BAS amplifiers and lasers by inducing modulations on pump and refractive index.
- The field regularization mechanism relies on the inward light coupling, which directs and concentrates light from each of the two half-spaces ($x < 0$ and $x > 0$) towards the center, with a significant intensity field enhancement and concentration of the emitted beam.
- When the center holds a high refractive index, with two side index maxima ($\Phi = \pi/4$), the local of PT-symmetry potential induces a temporally stable emission in the form of a narrow beam for a wide range of modulation amplitudes, this area of temporal stability partially coincides with the maximum concentration area.
- The system is studied under different working conditions of input power and mirror reflectivity, showing a substantial filed regularization, especially for pumps close to the laser threshold.
- The proposed scheme is general and could be implemented in other semiconductor lasers.

References

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- [2] W. W. Ahmed, R. Herrero, M. Botey and K. Staliunas, "Locally parity-time-symmetric and globally parity-symmetric systems," Phys. Rev. A 94, 053819 (2016).
- [3] W. W. Ahmed, J. Medina, R. Herrero, M. Botey, and K. Staliunas, "Stabilization of Broad-area semiconductor laser sources by simultaneous index and pump modulations", Opt. Lett. 43,11 (2018).
- [4] J. Medina, R. Herrero, M. Botey, and K. Staliunas, "Spatiotemporal Stabilization of Locally PT-symmetric Semiconductor Lasers", <http://arxiv.org/abs/1906.09146>.