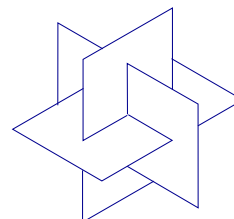




Weierstraß-Institut für Angewandte Analysis und Stochastik



DFG Research Center MATHEON
Mathematics for key technologies

Tailoring the dynamics of multisection lasers for 40 Gb/s direct modulation

Mindaugas Radziunas

In cooperation with U. Bandelow, M. Wolfrum, A. Glitzky, R. Hünlich (WIAS), U. Troppenz, J. Kreissl (HHI)

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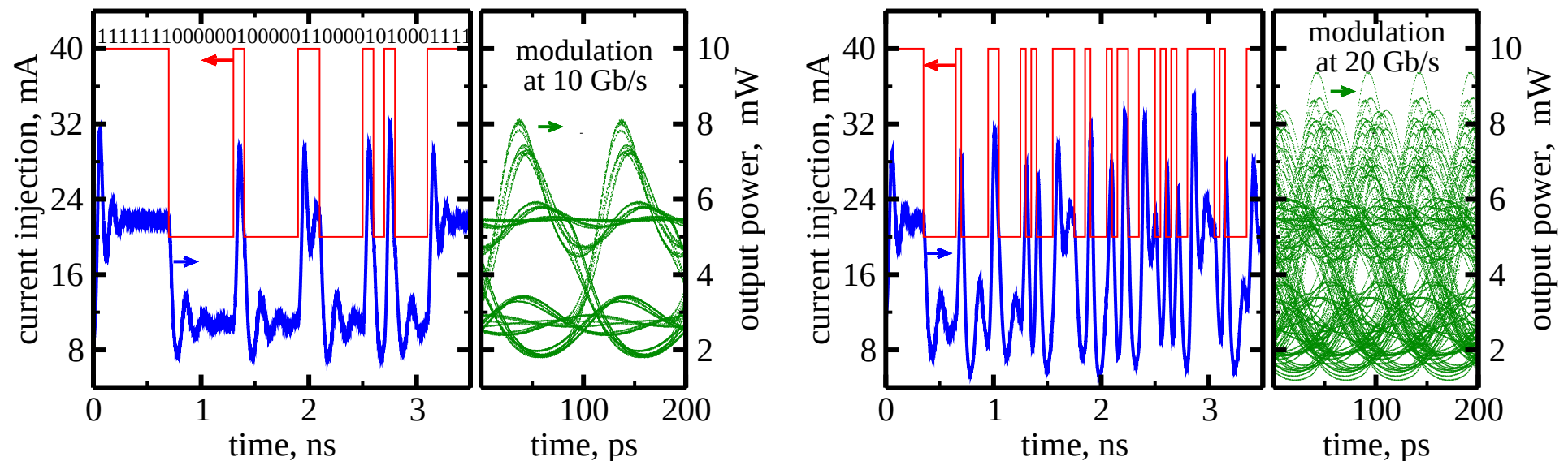
- ▷ Main goals;
- ▷ Basic methods to increase the speed potential;
- ▷ Finding the Photon-Photon resonance;
- ▷ Small and large signal analysis;
- ▷ Conclusions.

Main goals

Our aims

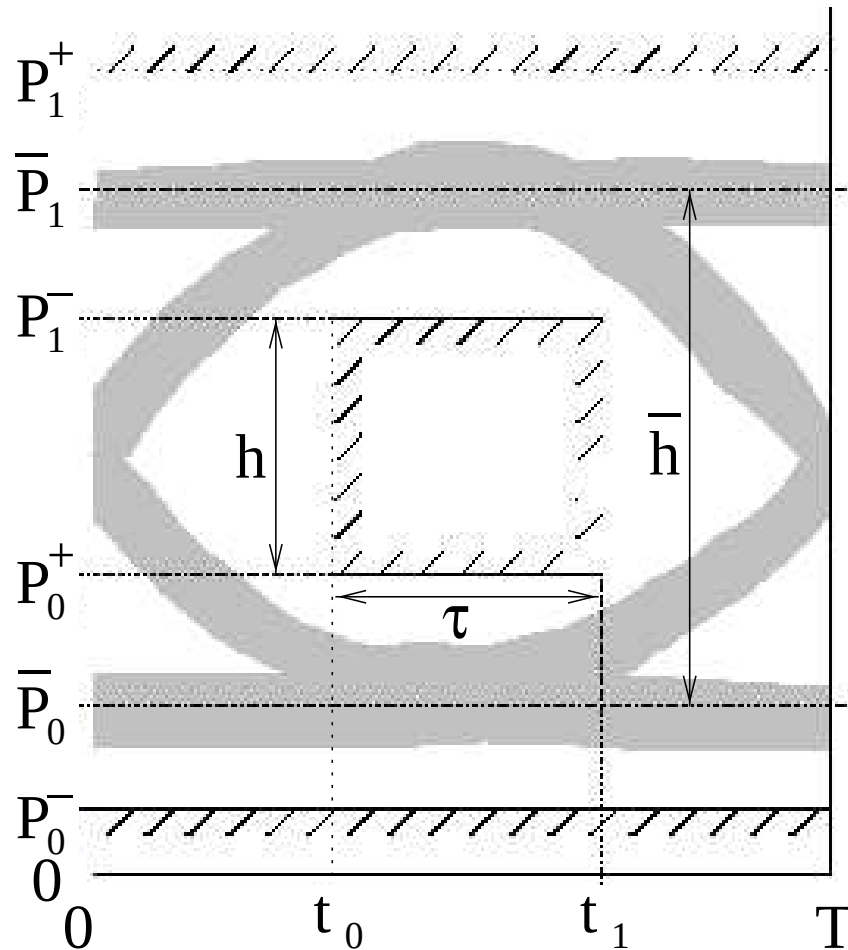
Conventional high-speed lasers are mainly limited by:

- ▷ interaction speed of carriers & photons
(CP resonance frequency)
- ▷ and/or by insufficient damping of relaxation oscillations



We seek to have a required laser performance
at a current modulation with 40 Gb/s PRBS.

System requirements: opened eye with good extinction



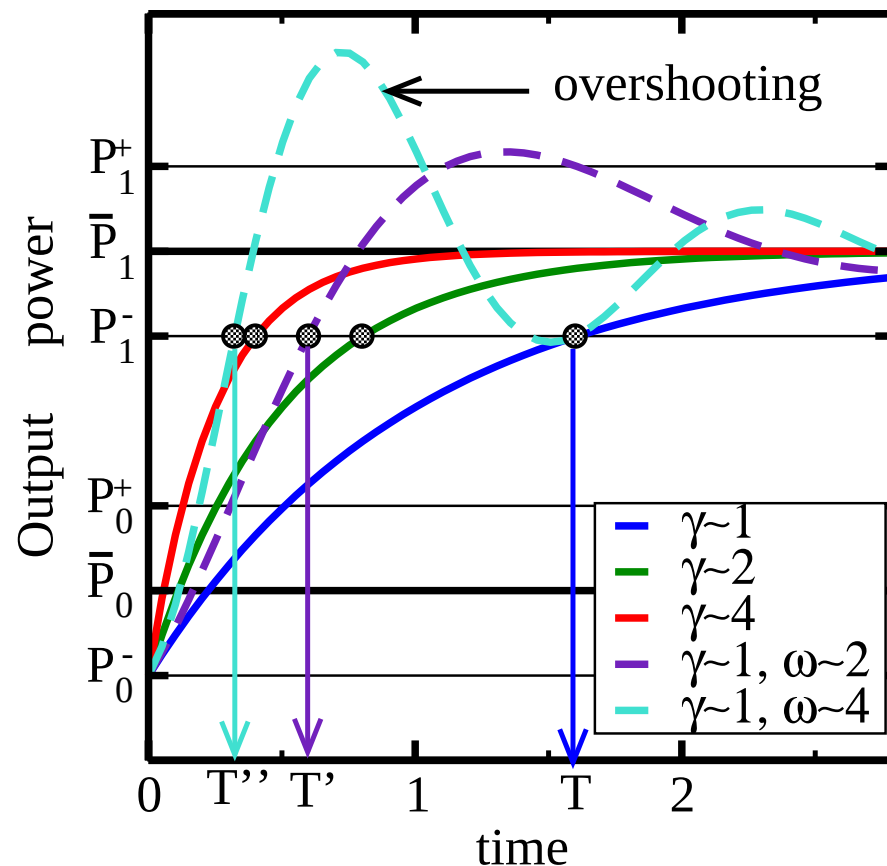
Main requirements for open eye:

- ▷ Opening height $\boxed{h > \bar{h}/2}$;
- ▷ Width of digital “1” and “0” layers $\boxed{|P_j^\pm - \bar{P}_j| < \bar{h}/4}$;
- ▷ Opening duration $\boxed{\tau > T/5}$;
- ▷ Extinction $\boxed{10 \log \left(\frac{\bar{P}_1}{\bar{P}_0} \right) \geq 3(dB)}$.

Basic methods to increase the speed potential

Fast transition between “0” and “1” states

To increase a bit transmission rate one needs to make transitions between $\bar{P}_0$ and $\bar{P}_1$ layers faster



Say, $P(t) - \bar{P}_1 \sim \Re e(e^{(i\omega - \gamma)t})$.

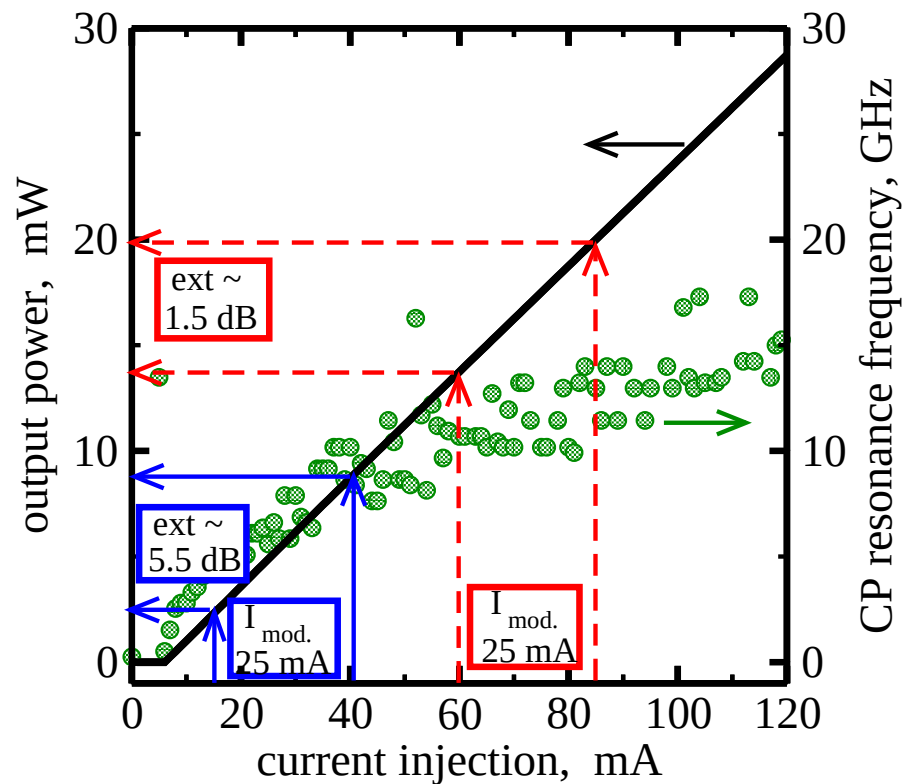
To achieve fast transitions between states one needs

- ▷ large damping γ
- ▷ or/and high relaxation frequency ω .

However, if ω/γ is too big, overshootings are expected!

Improving extinction $10 \log(\bar{P}_1/\bar{P}_0)$ of the eye diagram

Mean $\bar{P}_0$ and $\bar{P}_1$ states correspond to the constant current injection at “0” and “1” levels and are given by PI-characteristic



To achieve 3dB extinction one needs to have

- ▷ low mean injection
- ▷ or/and large enough modulation amplitude

But, CP resonance frequency at low injections is not very high!

Concept: to enhance resonance frequency

- ▷ Increase $f_{CP} \sim \sqrt{g'(I - I_{thr})}$ (up to 30 GHz) by increase of g' when optimizing transversal design (M.N. Akram ..., Semicond. Sci. Technol., 19, 2004)

but: to get a required high f_{CP} one still needs to apply large enough injection where extinction can be low !

- ▷ Increase of 3 dB bandwidth of modulation response function by, e.g.,
 - optical injection locking (L. Chrostowski ..., Proc. OFCC, OThM2, 2005)
 - exploiting intra-cavity or Photon-Photon (PP) resonance in multisection lasers (J.P. Reithmayer ..., Proc IPRM, 2005; U. Feiste, IEEE JQE, 34, 1998)

but: is damping of low frequency components (CP resonance) high enough for good performance of the laser at current modulation with large amplitude signal?

- ▷ Increase of damping of cw state by, e.g.,
 - injected beam at transparency wavelength of gain media

(G. Morthier ..., IEEE PTL, 16, 2004)

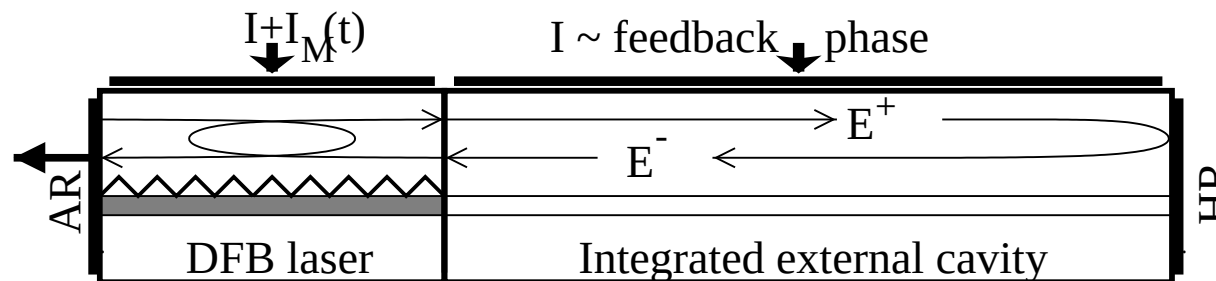
- optical feedback from resonator (V. Tronciu ..., submitted to Phys. Rev. A)

but: resonance frequency remains the same (dominated by CP resonance). Is improvement of damping alone high enough for system applications at 40 Gb/s modulation rate?

We shall show, that multisection laser concept allows both:
enhancement of PP resonance and
improvement of damping rate!

Finding the Photon-Photon resonance

The **simplest of possible *multisection* lasers** admitting dominance of the PP resonance with $f_{PP} \sim 40$ GHz is the single-mode laser with a short external cavity. (A. Tager ..., IEEE JQE, 30, 1994)



To simulate and to analyze the performance of this device we use the Traveling Wave model and its mode approximation system (Tutorial MB1)

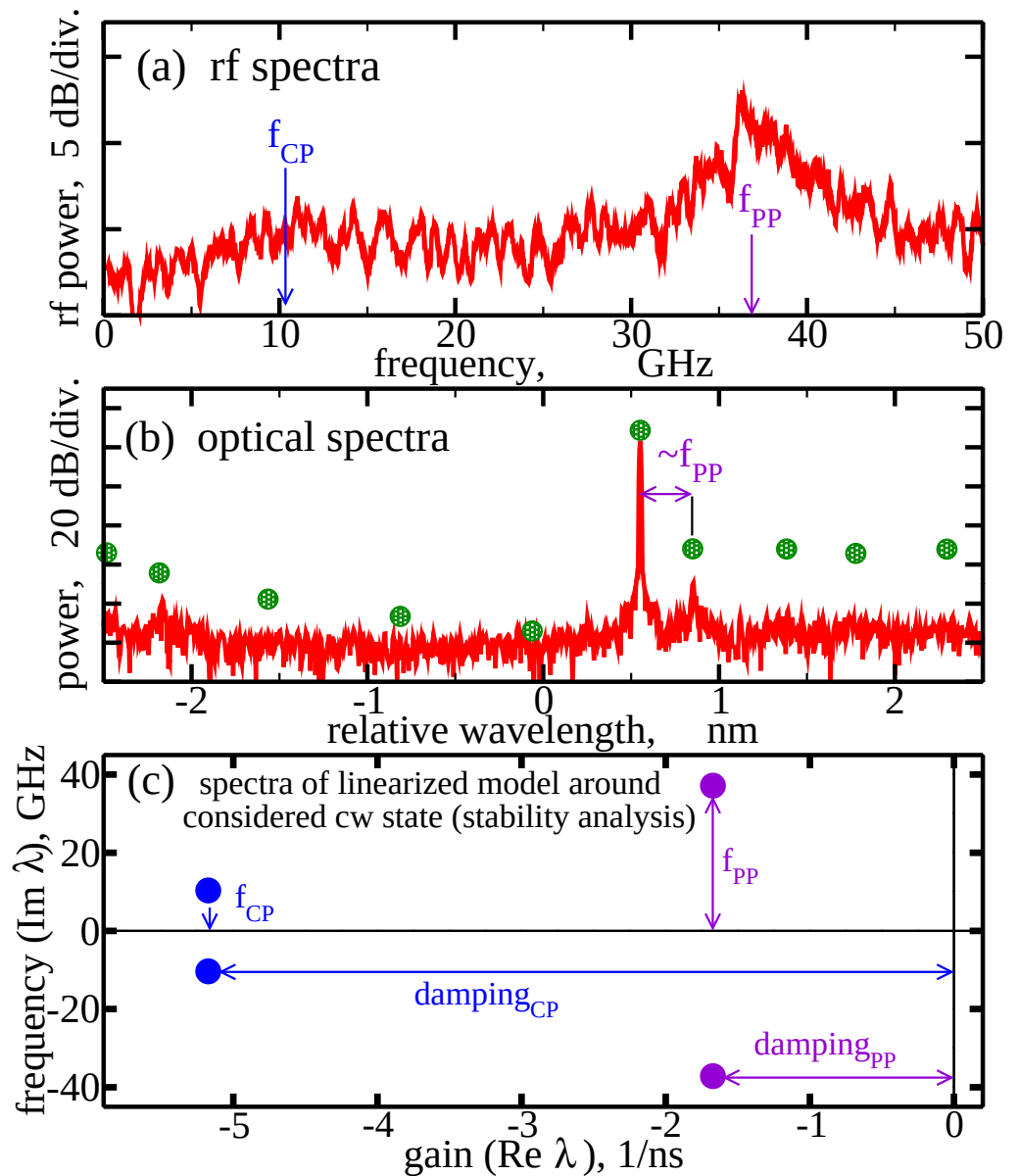
(LDSSL-tool, <http://www.wias-berlin.de/software/ldsl>)

Photon-Photon resonance

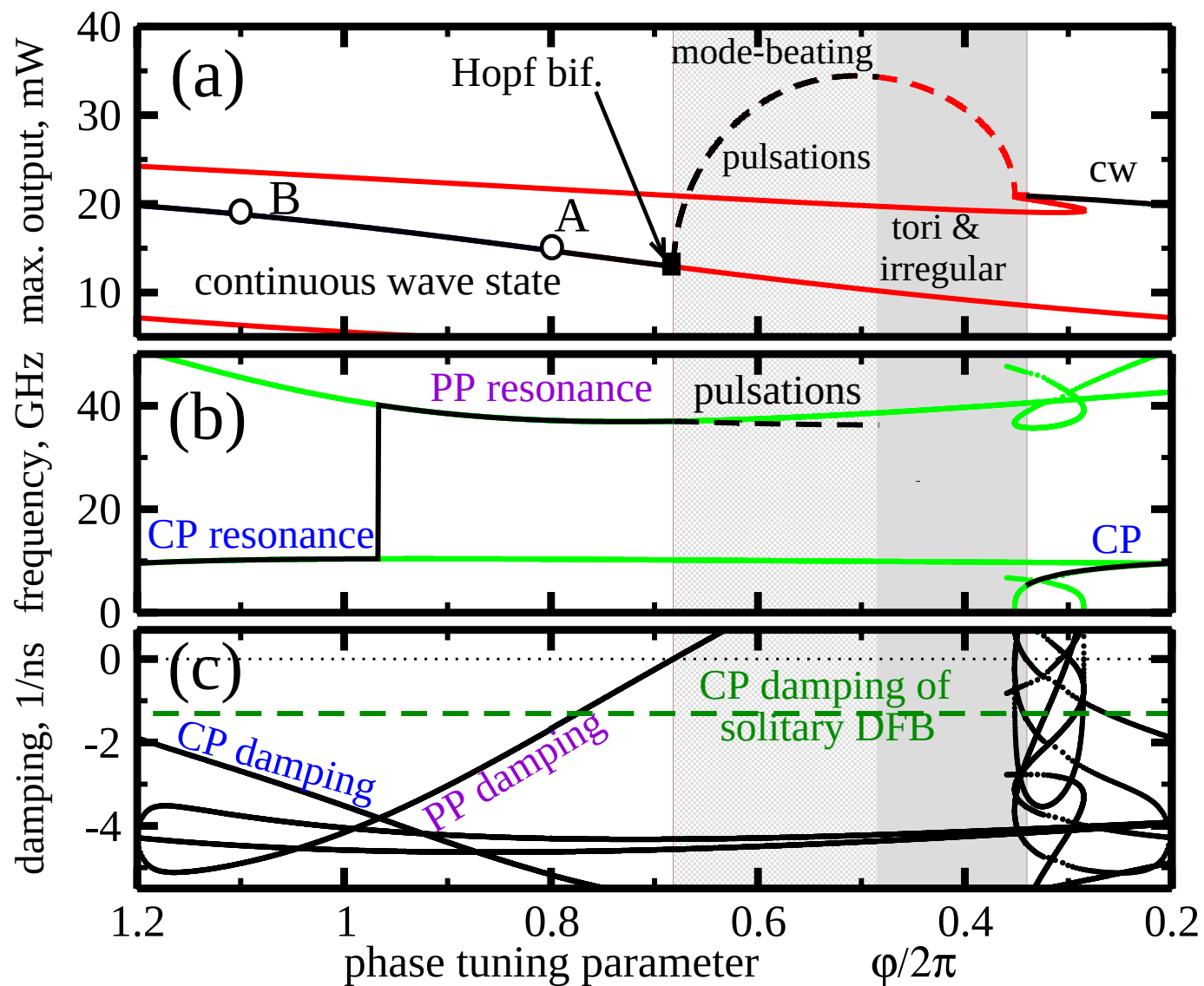
Suitably selecting optical field feedback strength and phase one can achieve dominance of the PP resonance.

This resonance is induced by frequency separation of longitudinal modes

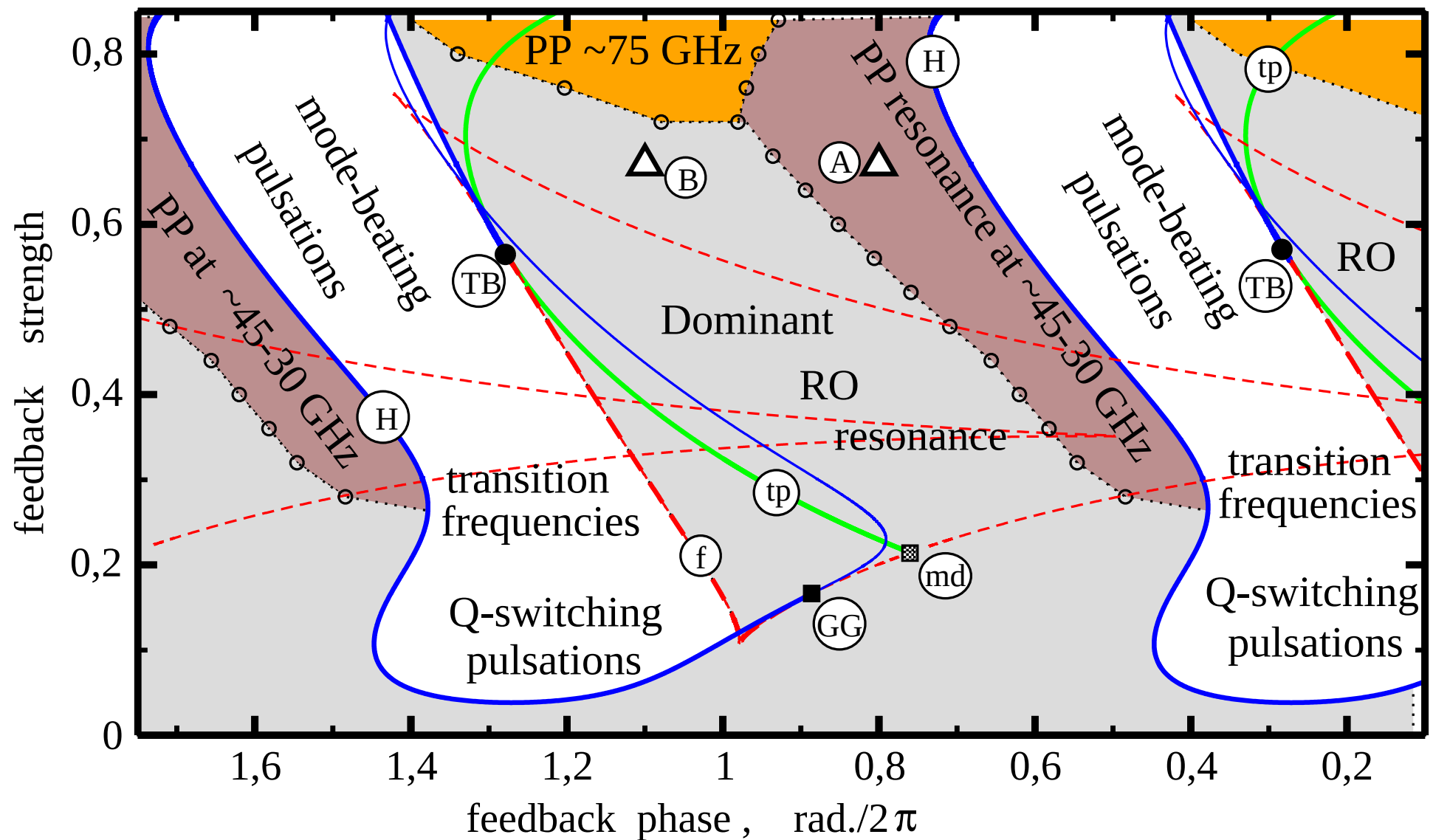
(M. Radziunas ..., in *Optoelect. Devices*, Springer, 2005).



Finding intervals with dominant PP resonance on parameter axis

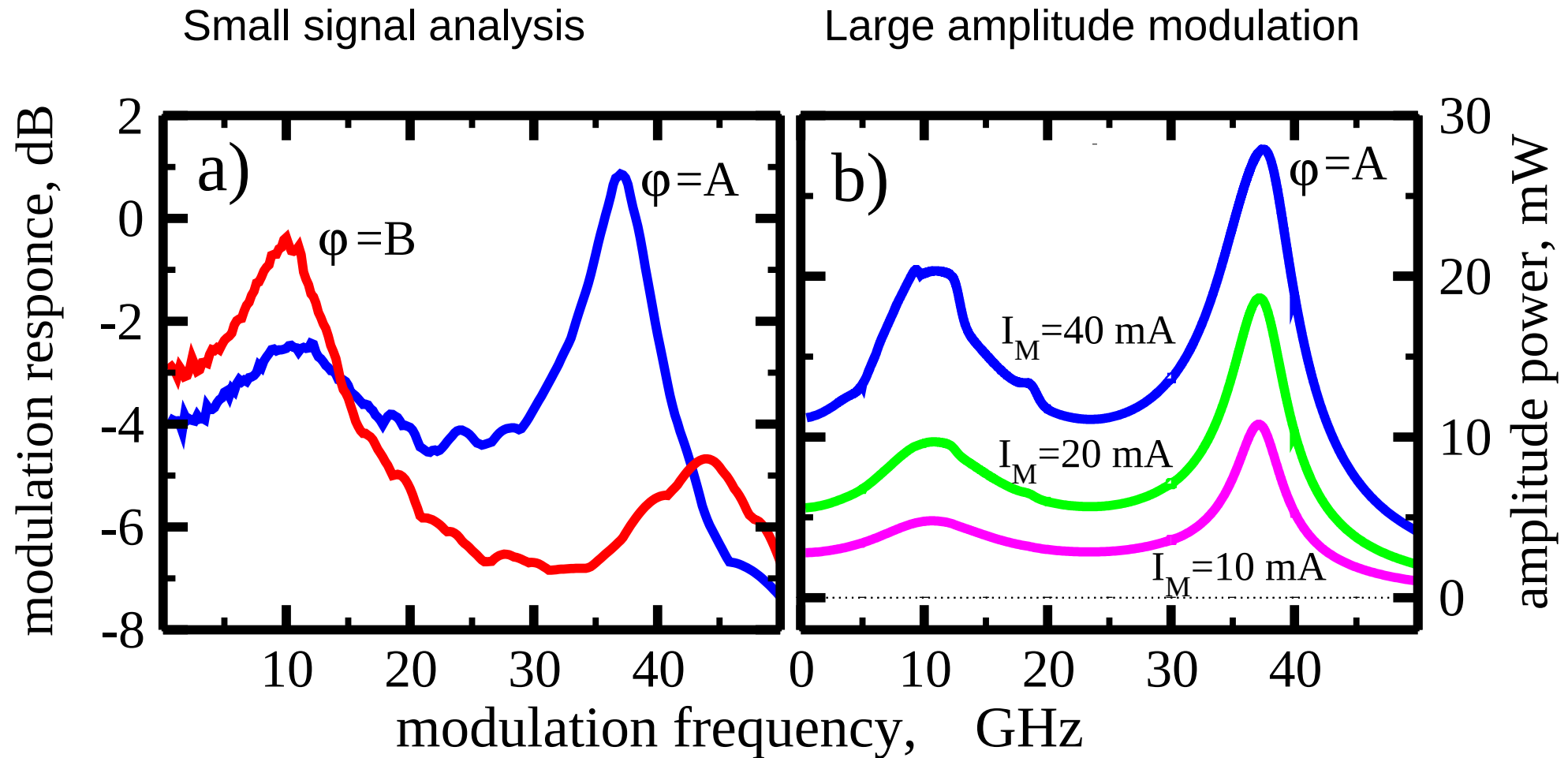


Finding regions with dominant PP resonance in parameter space

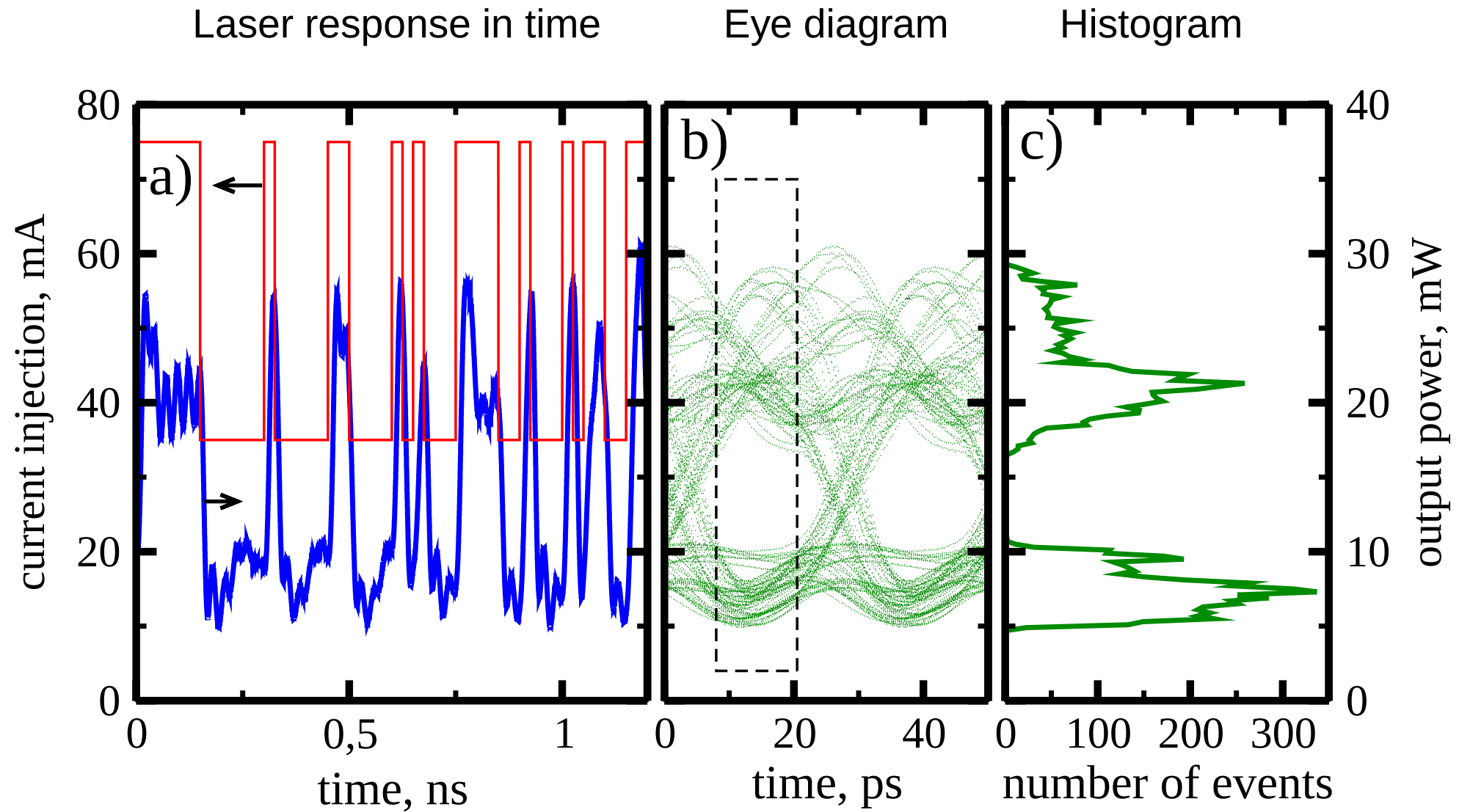


Small and large signal analysis

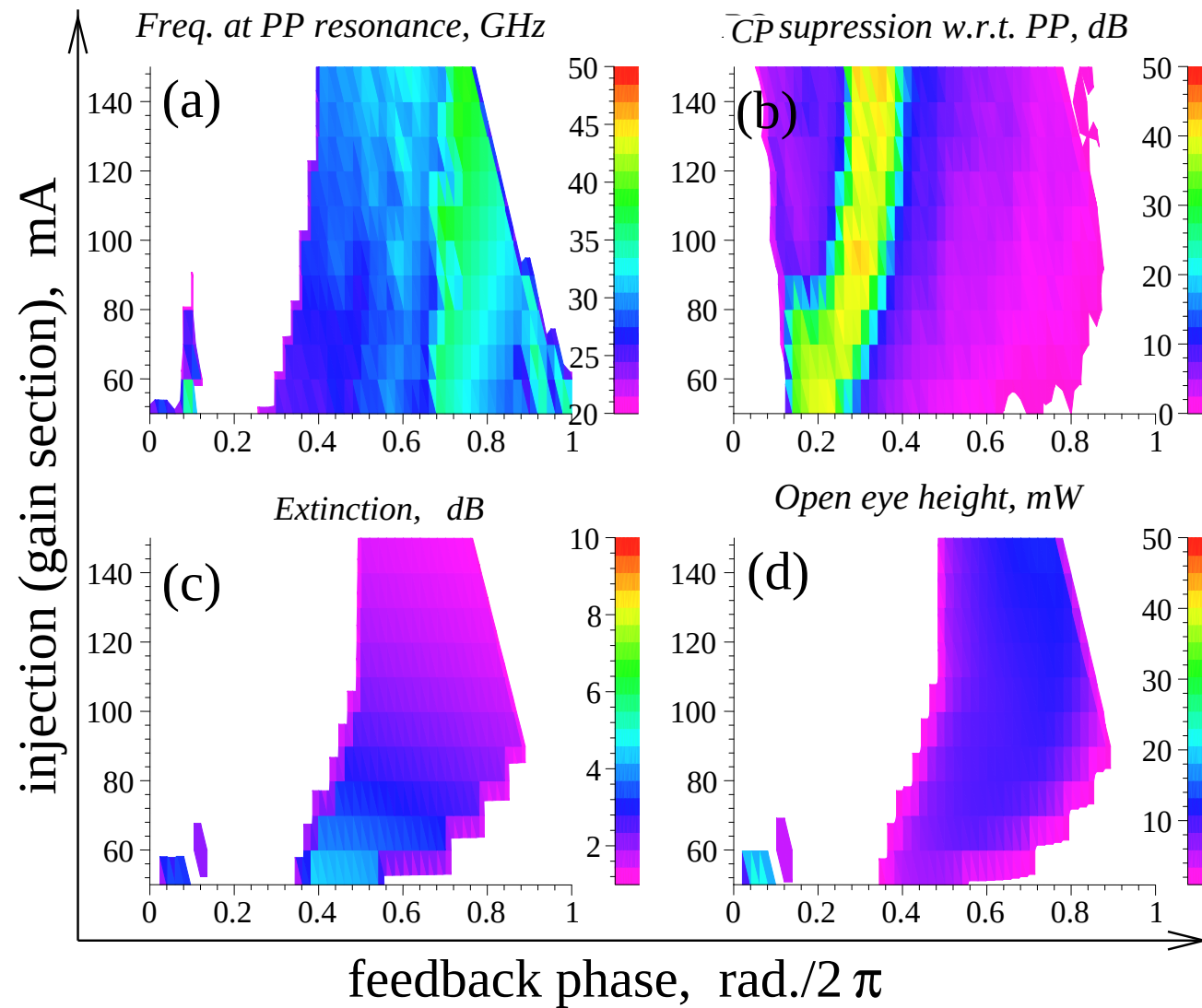
Current modulation with periodic signal



Current modulation with 40 Gb/s $2^7 - 1$ PRBS



Areas of opened eyes in the parameter plane



Above: unmodulated laser. PP resonance frequency and relative suppression of CP.

Below: directly modulated laser with 40 Gb/s PRBS. Open eye extinction and amplitude.

Conclusions

Conclusions

- ▷ The PP resonance can dominate over the CP resonance in **multisection** lasers;
- ▷ For dominance of the PP resonance we need **large enough feedback** and a **possibility to tune the feedback phase**;
- ▷ Need to select the conditions where **PP resonance dominates** and **the damping is improved**;
- ▷ Opened eyes at 40 Gb/s current modulation with PRBS;
- ▷ Best extinction of eye diagrams at **lower currents**;
- ▷ Better performance of lasers with **higher differential gain**.
- ▷ **Other multisection laser configurations are also possible!**