



HAL
open science

Pulse Doublets Generated by a Frequency-Shifting Loop Containing an Electro-Optic Amplitude Modulator

Hongzhi Yang, Marc Brunel, Marc Vallet, Haiyang Zhang, Changming Zhao

► **To cite this version:**

Hongzhi Yang, Marc Brunel, Marc Vallet, Haiyang Zhang, Changming Zhao. Pulse Doublets Generated by a Frequency-Shifting Loop Containing an Electro-Optic Amplitude Modulator. Conference on Lasers and Electro-Optics Europe and European Quantum Electronics Conference 2019 (CLEO-Europe/EQEC 2019), 2019, Munich, Germany. IEEE (ISBN: 978-1-7281-0469-0), IEEE Xplore Digital Library, pp.1-1, 2019, 2019 Conference on Lasers and Electro-Optics Europe & European Quantum Electronics Conference (CLEO/Europe-EQEC). 10.1109/CLEOE-EQEC.2019.8872459 . hal-02470320

HAL Id: hal-02470320

<https://hal.science/hal-02470320>

Submitted on 12 Feb 2020

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

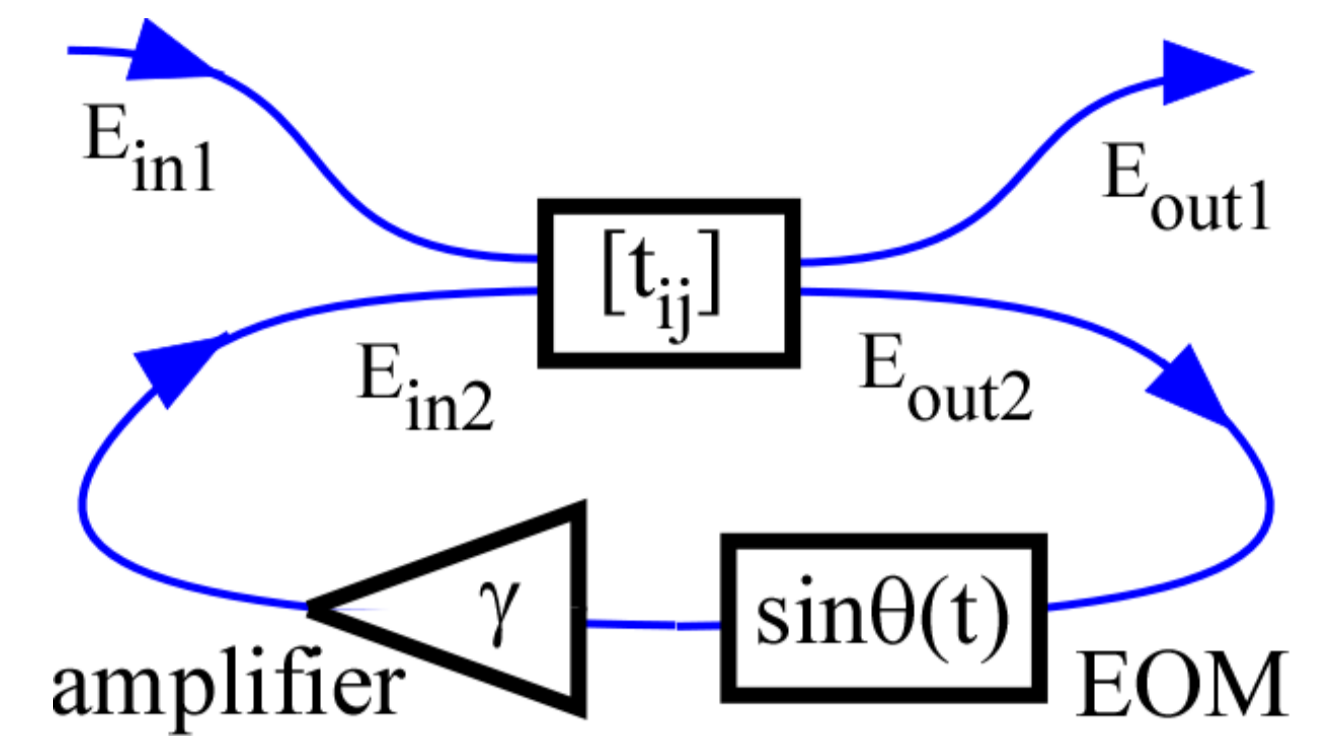
Introduction

Frequency-Shifted feedback Loops FSL, both active or passive, are promising solutions for pulse generation with high repetition rate. FSL usually contains an acousto-optic frequency shifter AOFS for single-side band modulation [1-3]. This leads to limited tunability and low modulation frequency f_m .

Conversely: the use of in-loop electro-optic amplitude modulators EOM permits high modulation, wide bandwidth and integration [4-5].

However, due to dual-side band modulation, EOM lead to new regimes

→ Here, theoretical and experimental study of FSL with EOM



Theoretical model

E_{in1} CW:

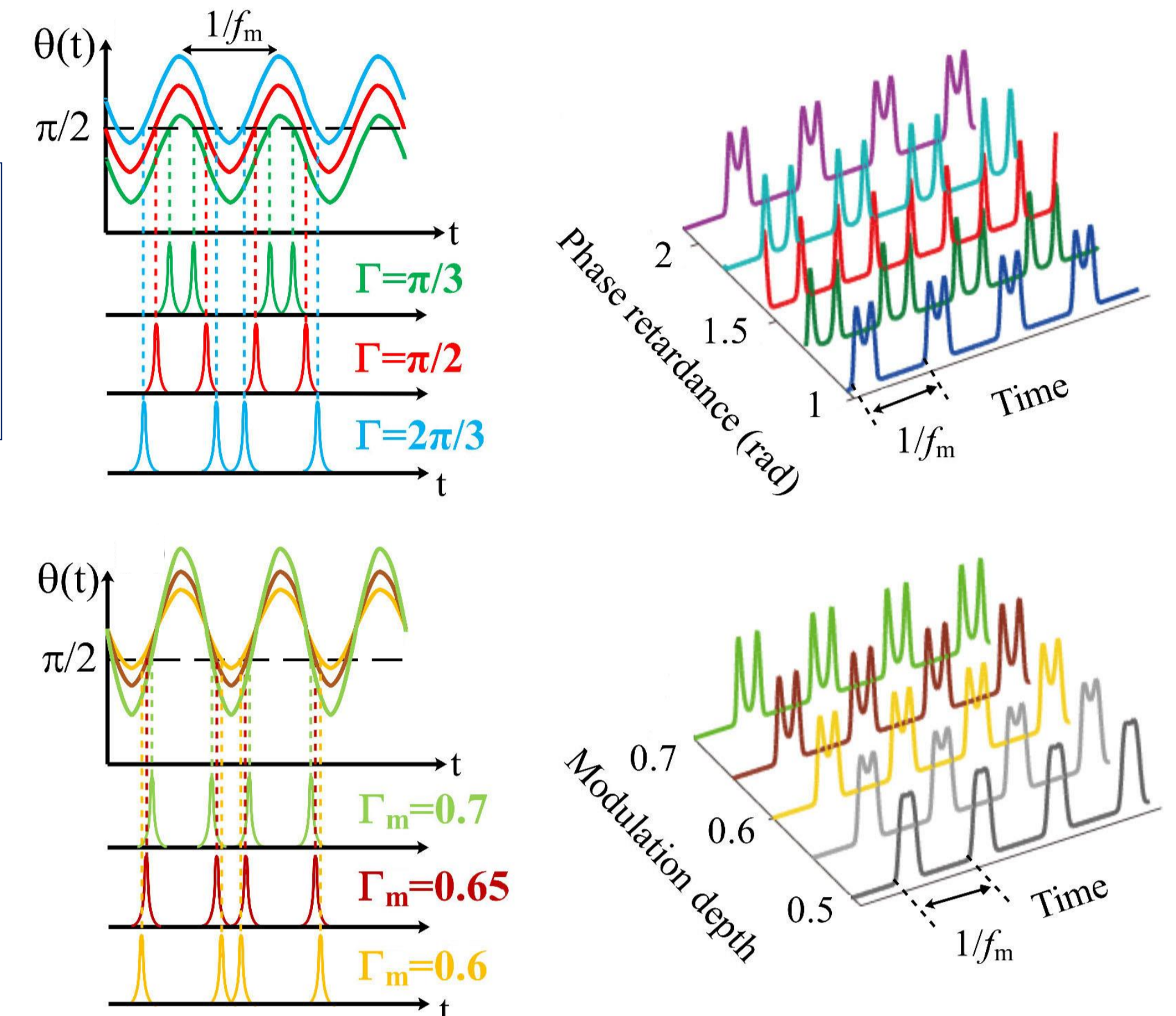
$$E_{out1}(t) = \left(t_{11} + t_{12}t_{21} \sum_{p=1}^N \left(t_{22}^p \gamma^p \prod_{q=1}^p \sin(\theta(t - q\tau)) \right) \right) E_{in1}$$

With modulation at f_m : $\theta(t) = \Gamma + \Gamma_m \sin(2\pi f_m t)$ Γ phase retardance, Γ_m modulation depth

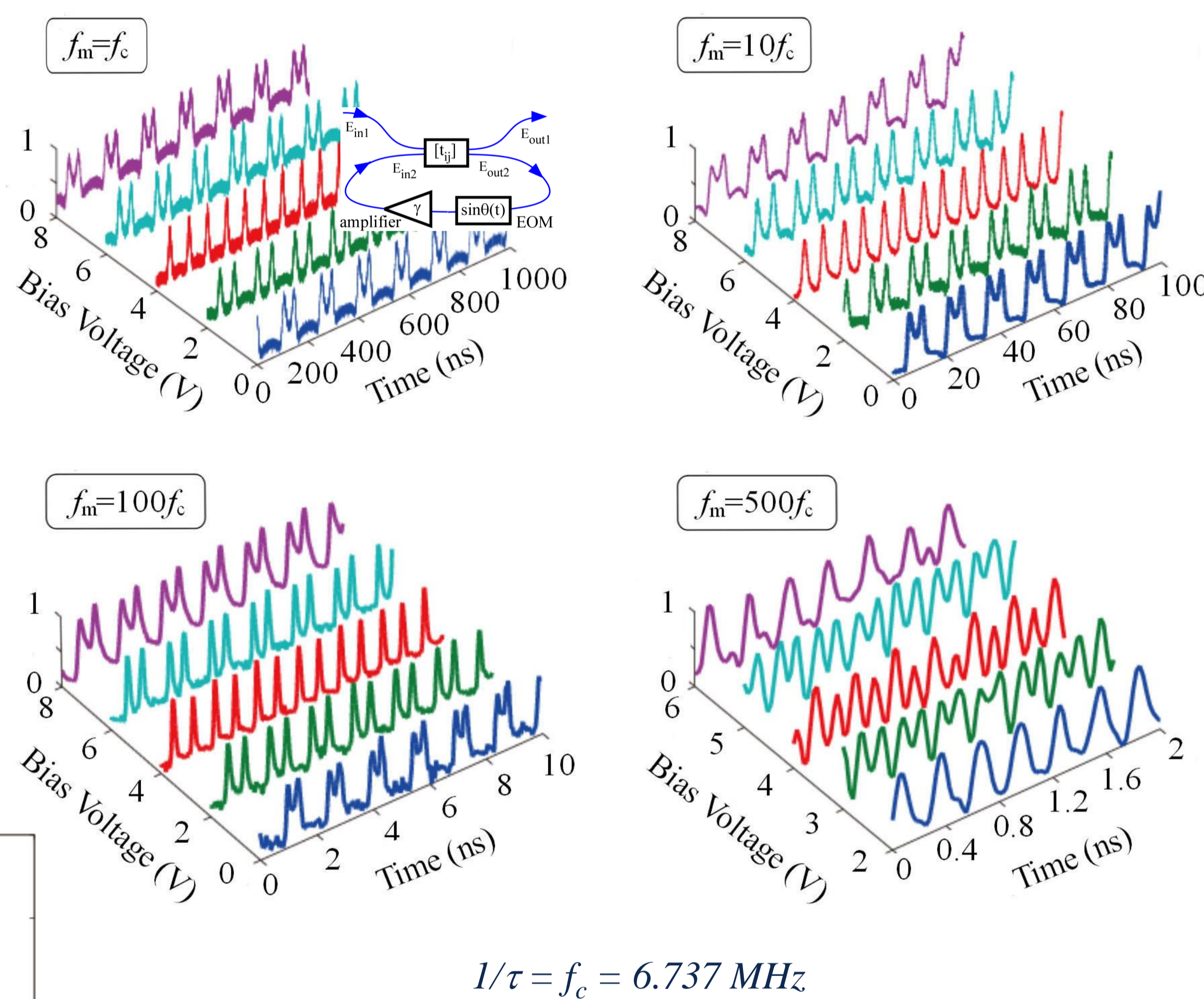
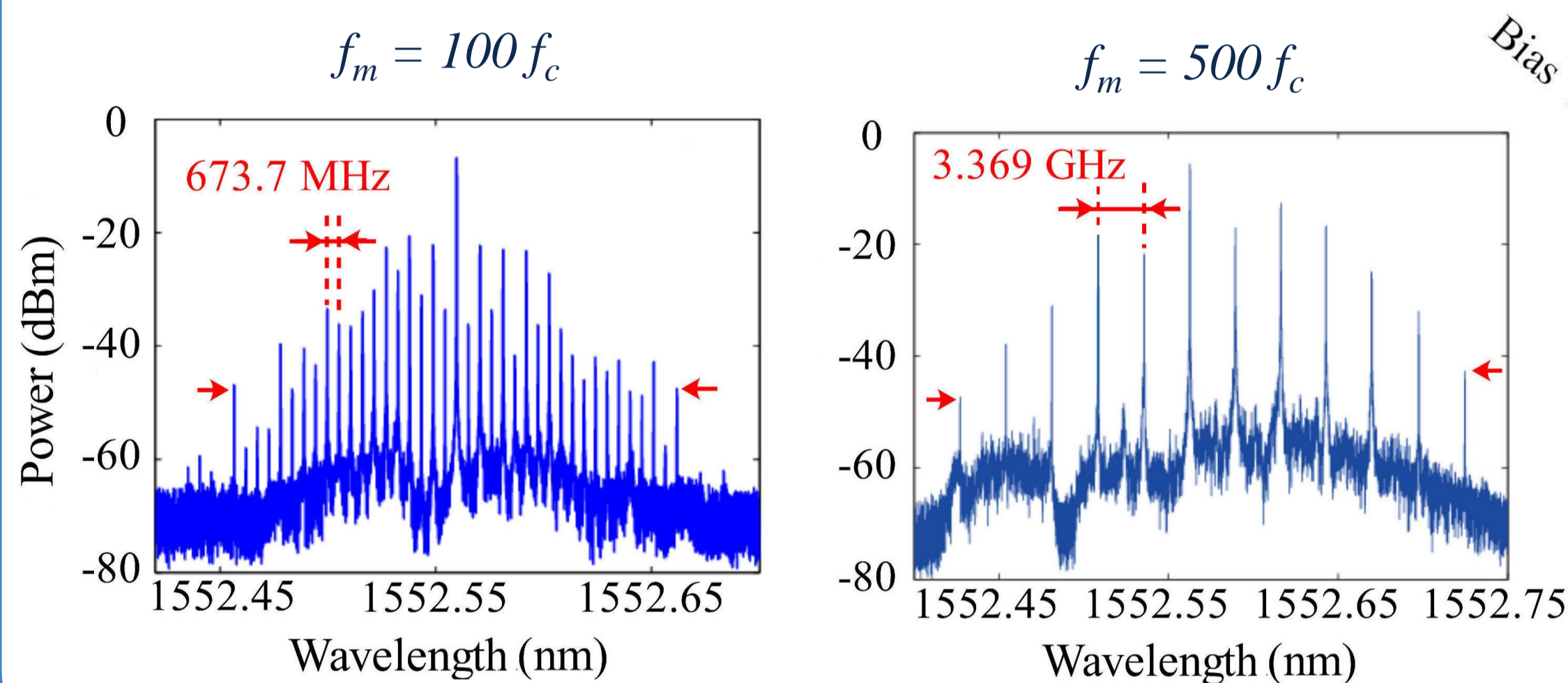
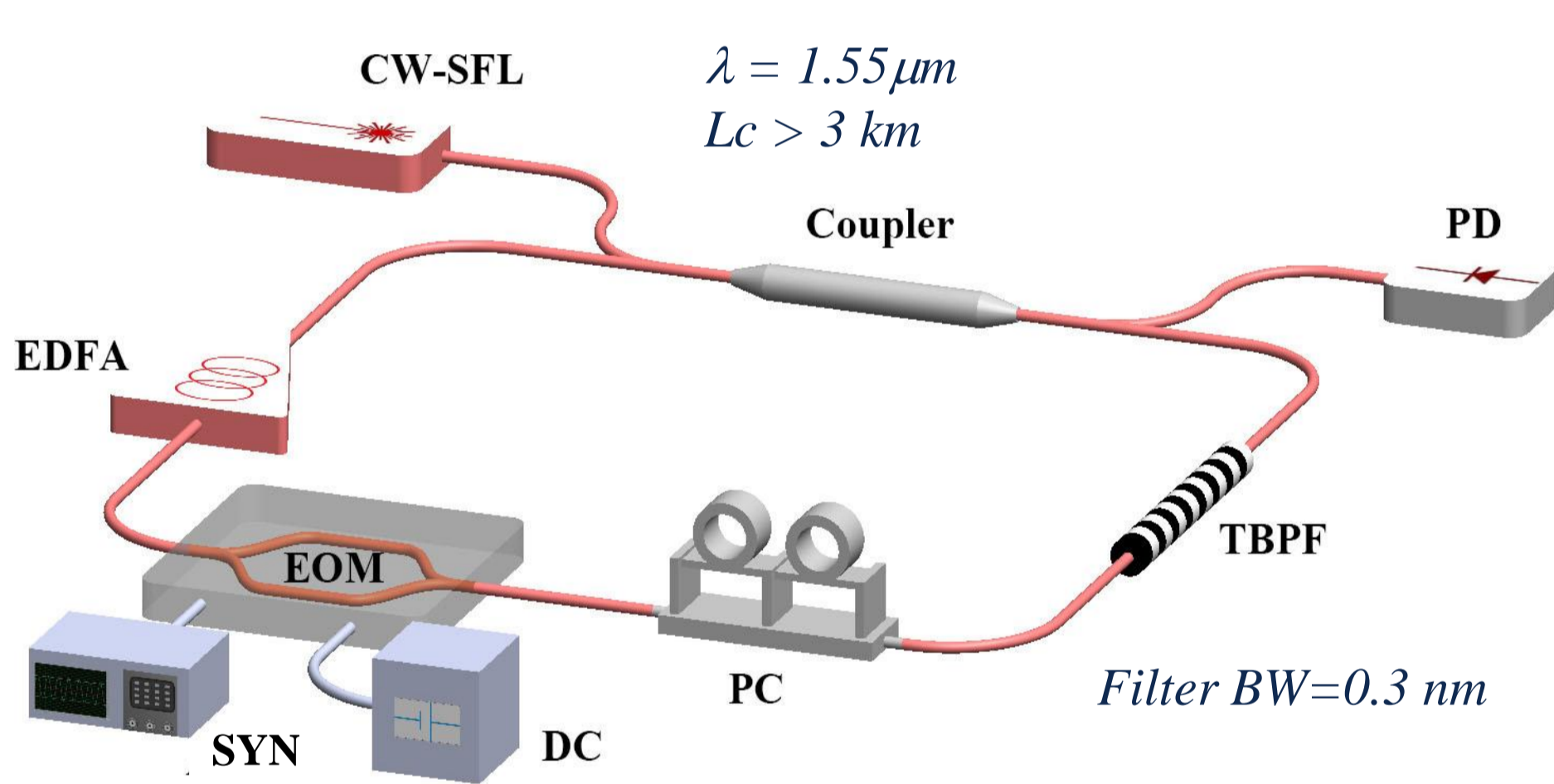
For integer Talbot condition [1-2]: $f_m = n/\tau$

If $N \gg 1$ $E_{out1}(t) = \frac{t_{11} - \gamma(t_{11}t_{22} - t_{12}t_{21}) \sin \theta(t)}{1 - \gamma t_{22} \sin \theta(t)} E_{in1}$ → E_{out1} pulsed for $\theta(t) \approx \pi/2$
2 pulses per period $1/f_m$

Parameters
 $[t] = \begin{bmatrix} 0.44 & 0.65i \\ 0.43i & 0.67 \end{bmatrix}$
 $N = 30$
 $\gamma = 0.9$



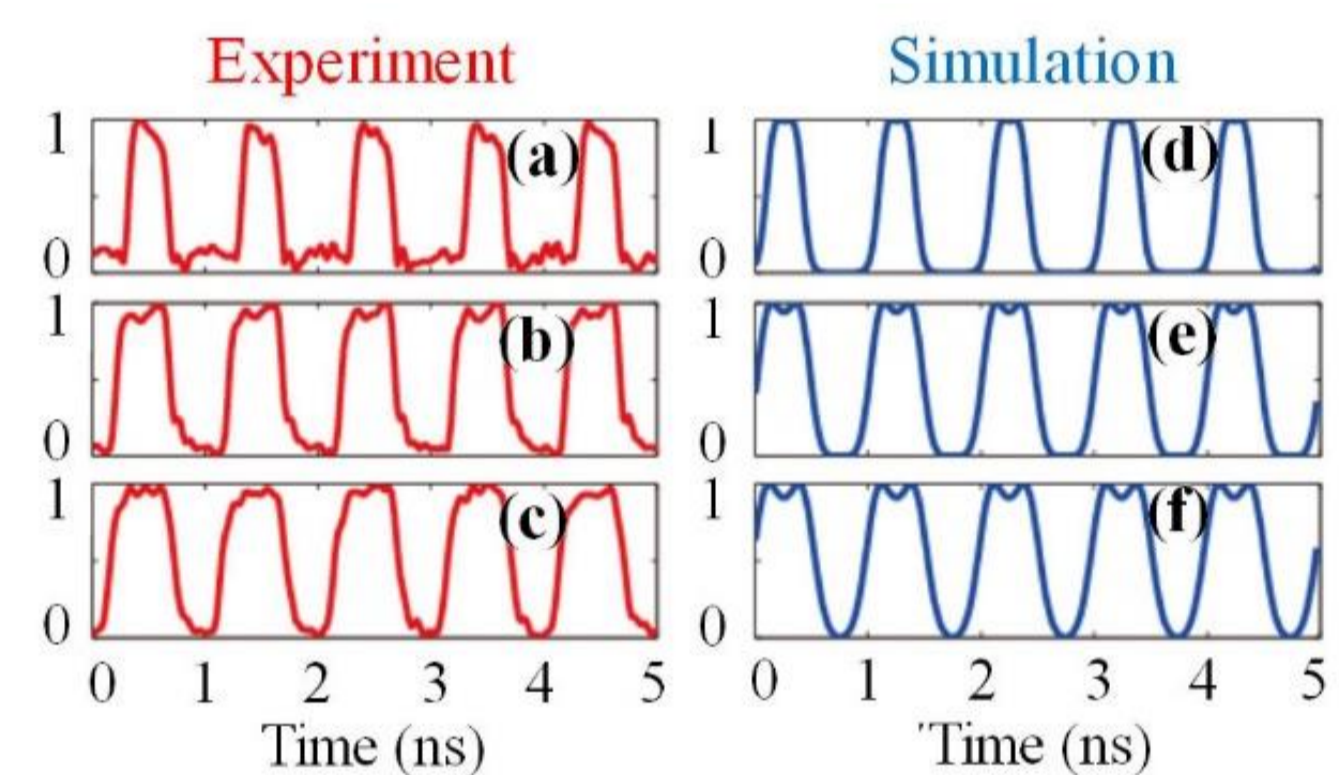
Experimental results



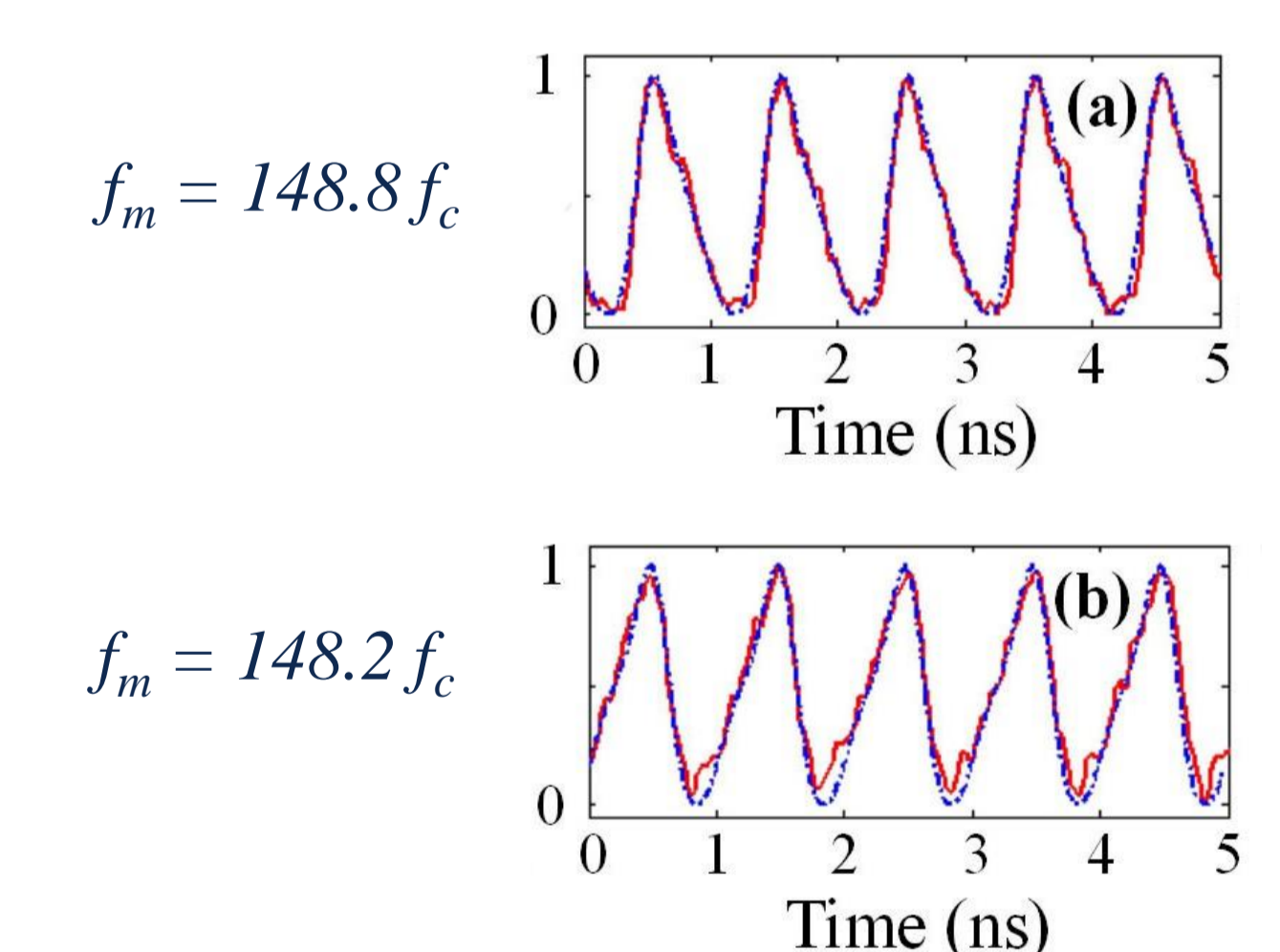
(H. Yang et al , Optics Express, revision)

Waveform generation

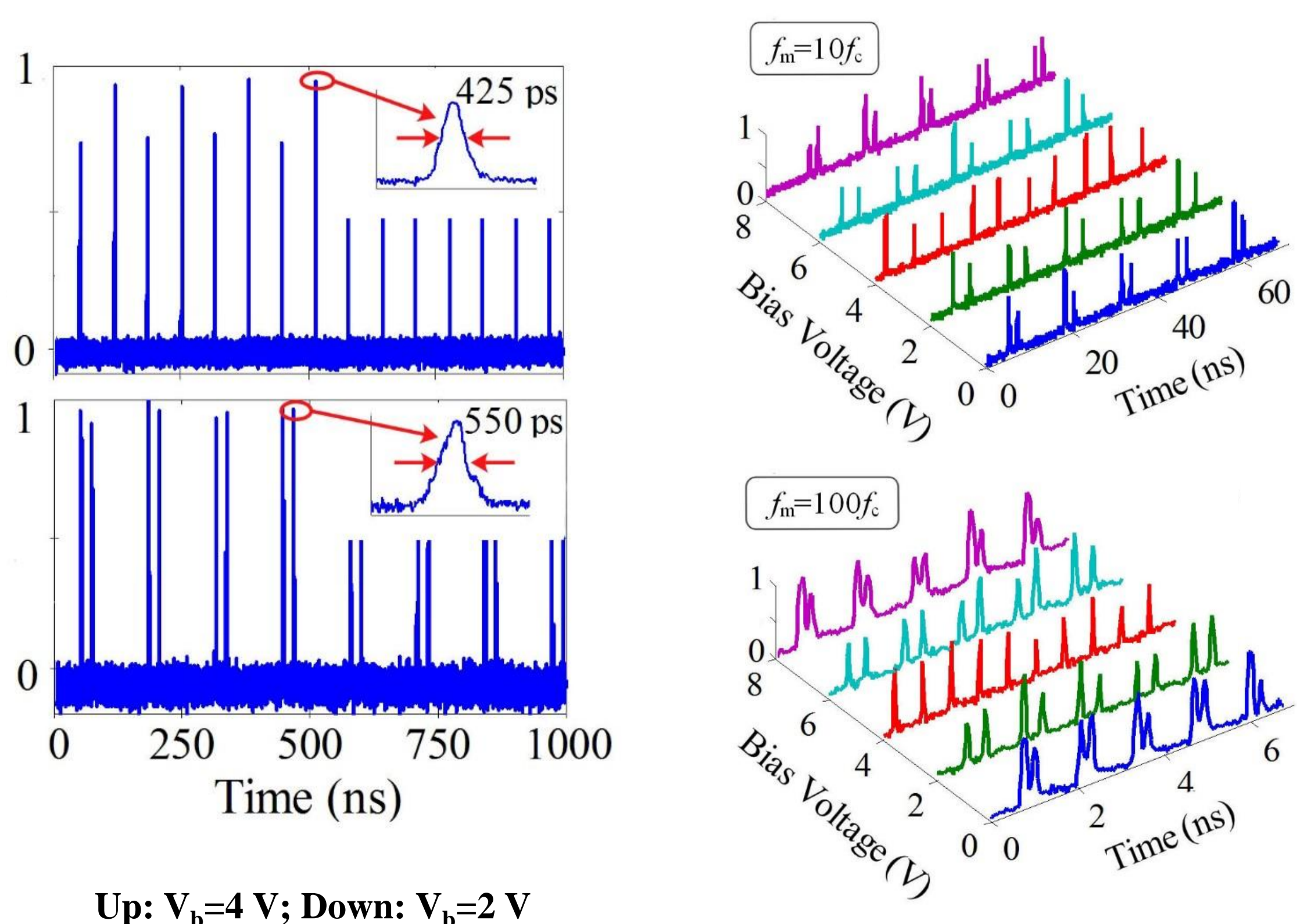
Rectangular shape



Sawtooth waveform



Mode-locked double-pulse regime



Up: $V_b = 4$ V; Down: $V_b = 2$ V

Conclusion

- Observation of original double-pulse regime
- Theoretical model in agreement with experiments
- Repetition-rate tunability from MHz to GHz
- frequency comb width up to 40 GHz
- waveform generation: rectangle, sawtooth,...

Forthcoming

- Phase modulation vs intensity modulation
- Frequency-to-time mapping (as in [6] with AOFS)
- Repetition-rate tunability from MHz to GHz
- Fractional Talbot condition $f_m = p/q f_c$: towards high repetition rates

References

- [1] H.G. de Chatellus et al, Phys. Rev. A 2013 [4] L. Wang et al, CLEO 2017
 [2] C. Schnébelin et al, CLEO 2017 [5] F. Tian, IEEE J. Lightwave Technol. 2011
 [3] H. Yang et al, IEEE Photon. J. 2017 [6] H.G. de Chatellus et al, Optica 2016