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GHz-rate pulse pairs generated by a frequency-shifting loop containing an electro-optic modulator

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

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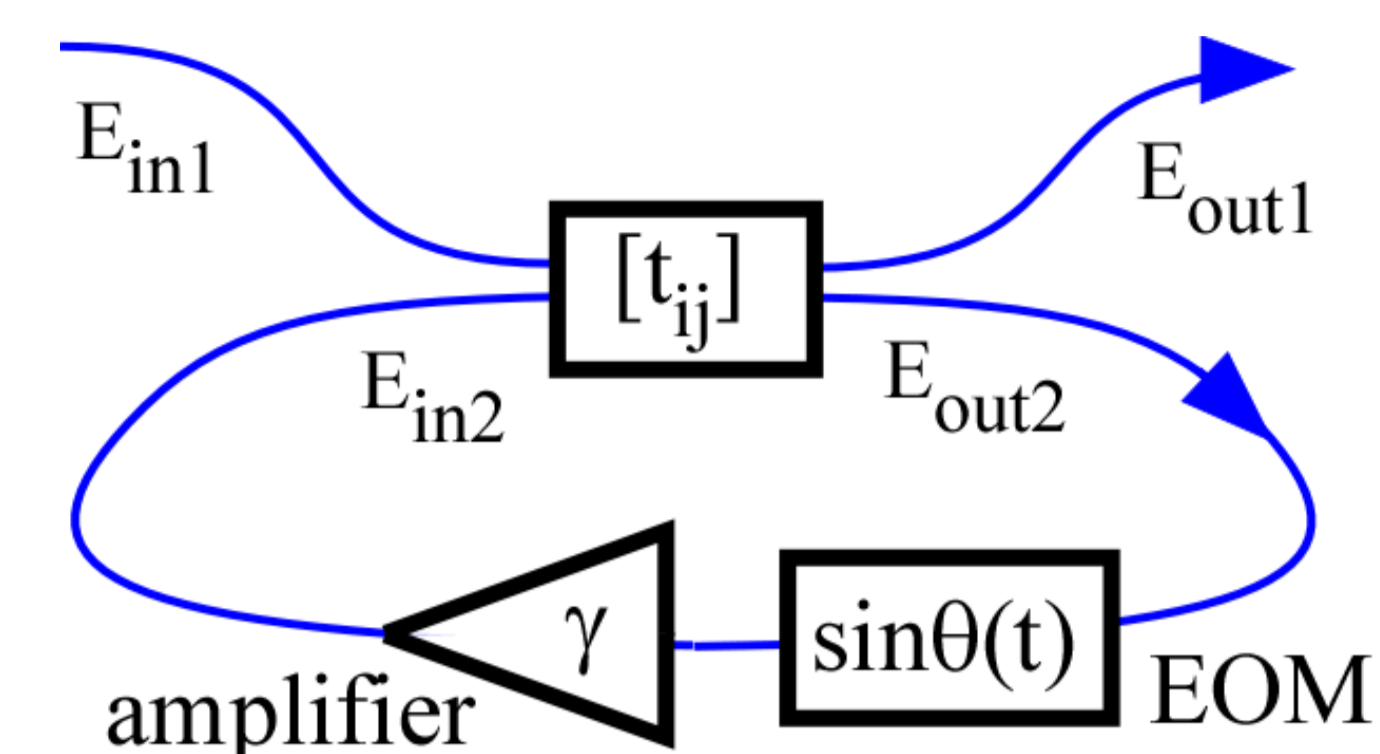
Introduction

Frequency-shifted feedback loops, both active or passive, are promising solutions for pulse generation with high repetition rate. FSFL usually contains an acousto-optic frequency shifter AOFS for single-side band modulation [1-3]. This leads to poor 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 FSFL with EOM



Theoretical model E_{in1} cw + modulation at f_m

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

$$\theta(t) = \Gamma + \Gamma_m \sin(2\pi f_m t)$$

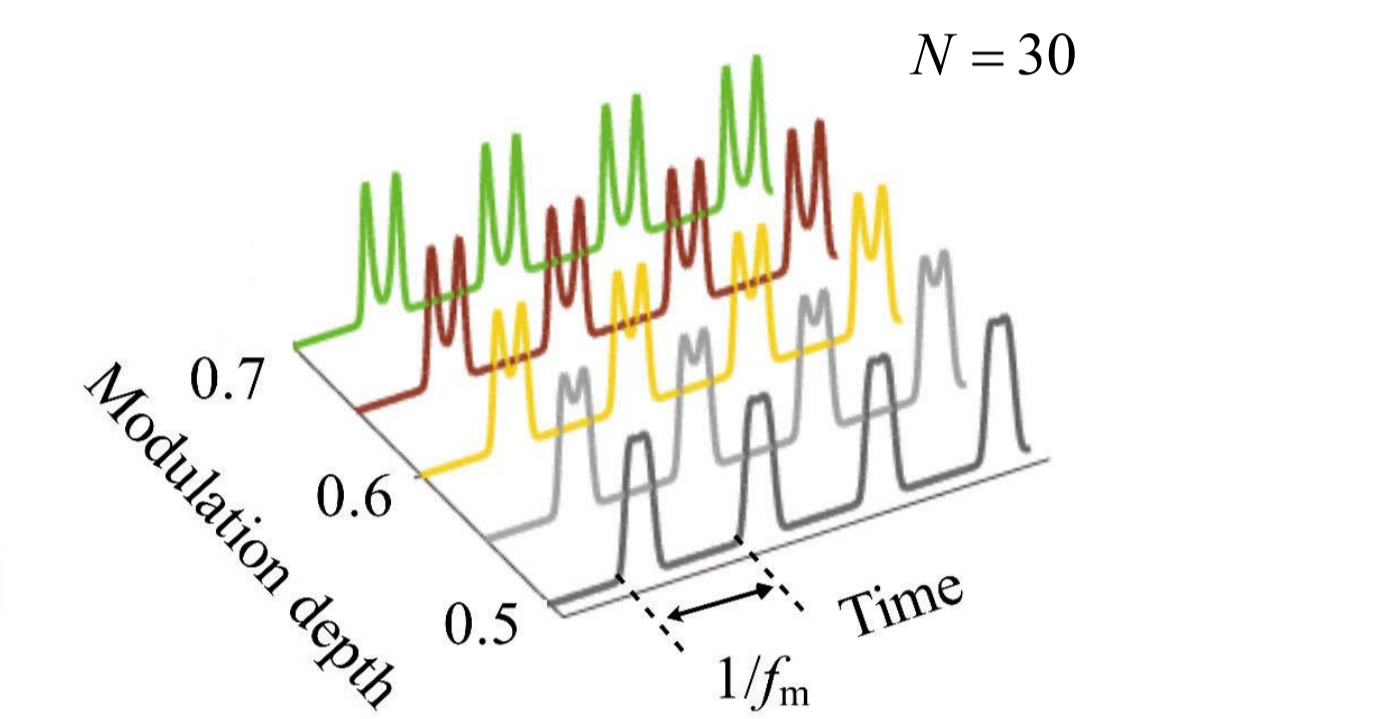
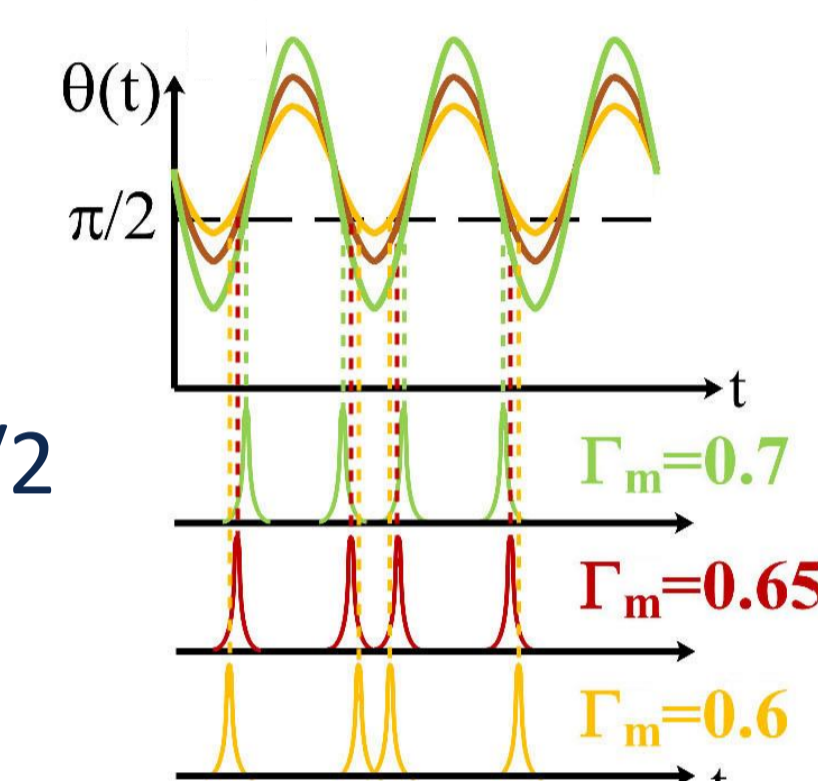
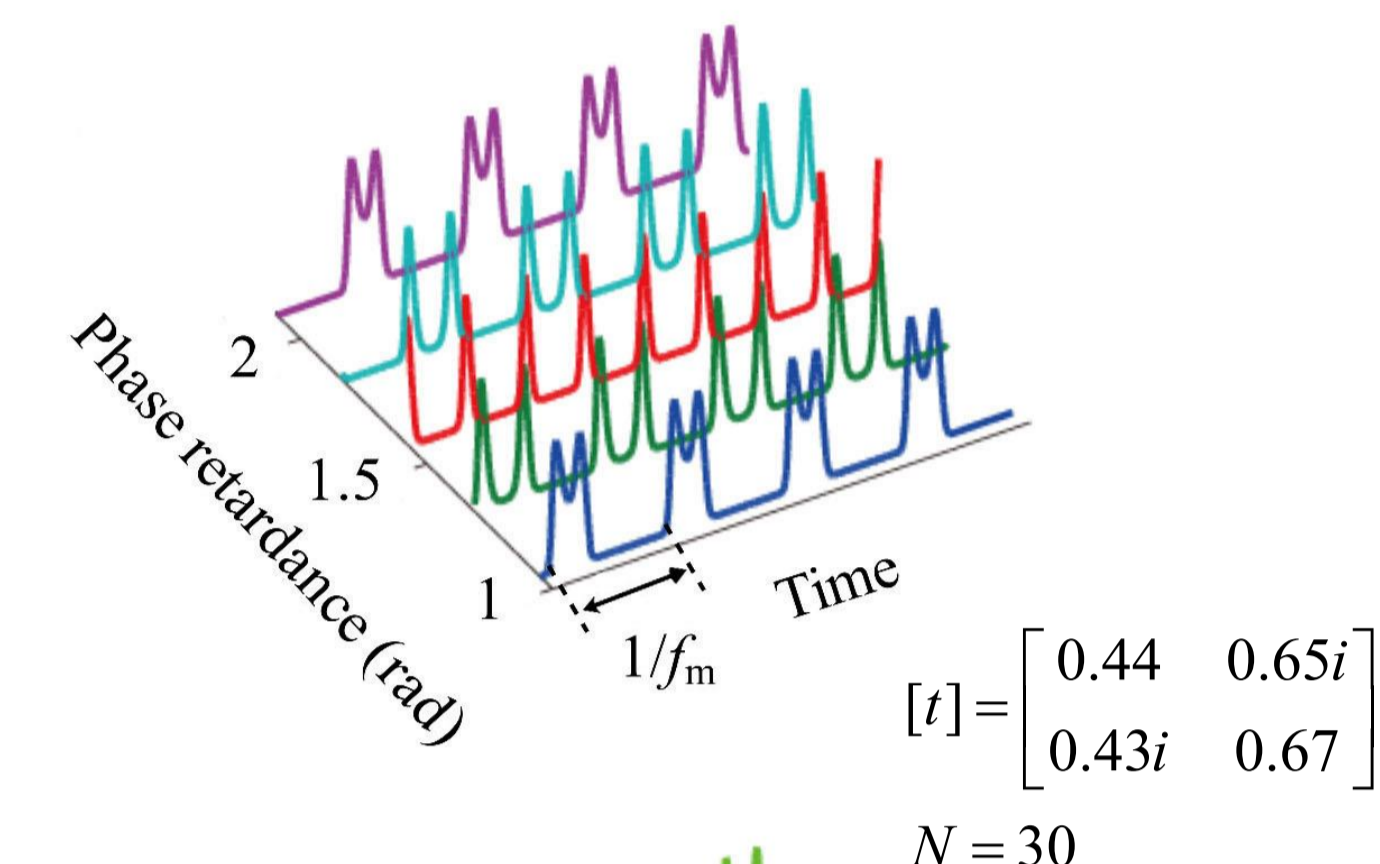
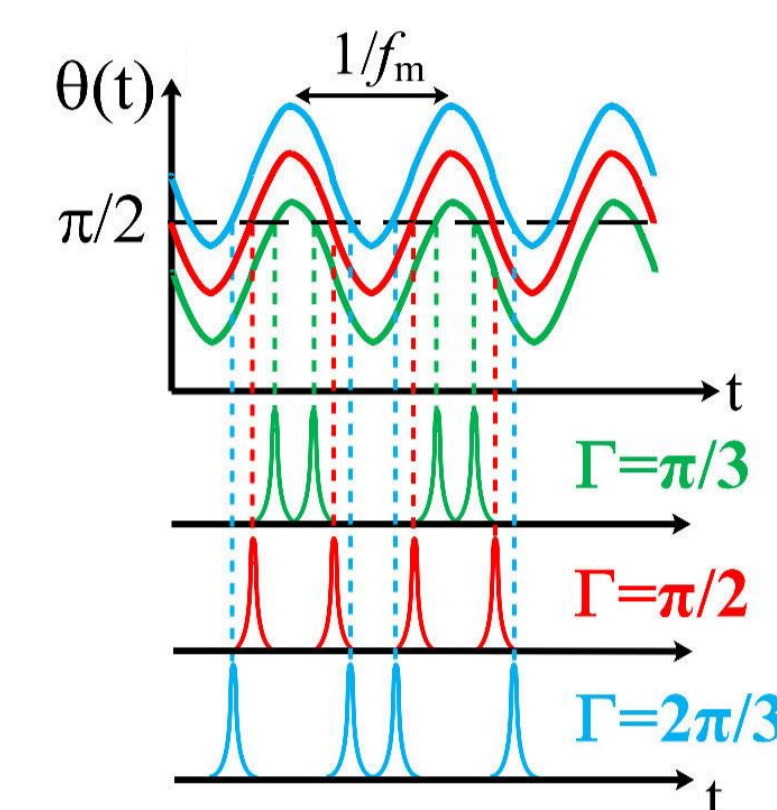
For integer Talbot condition [1-2]: $f_m = n/\tau$

If $N \gg 1$

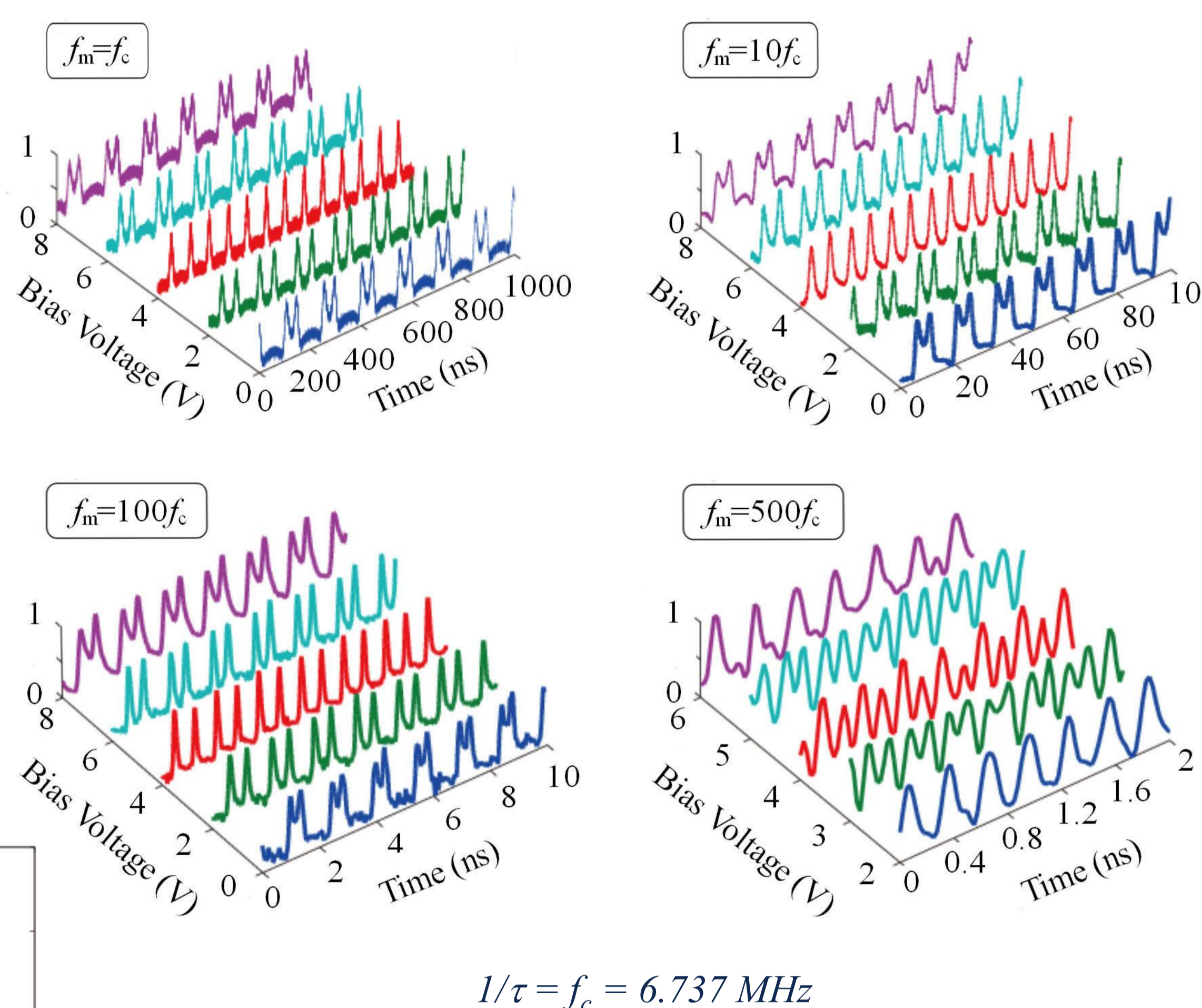
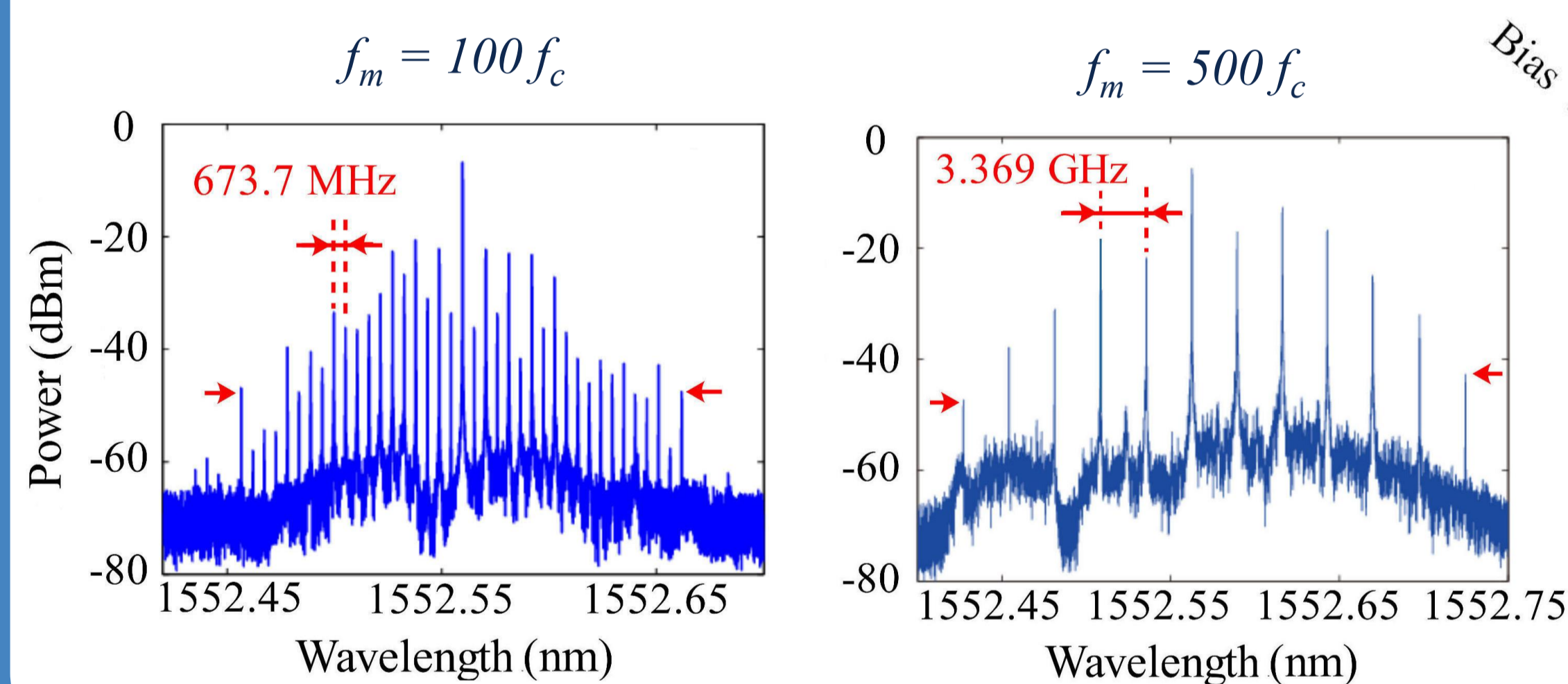
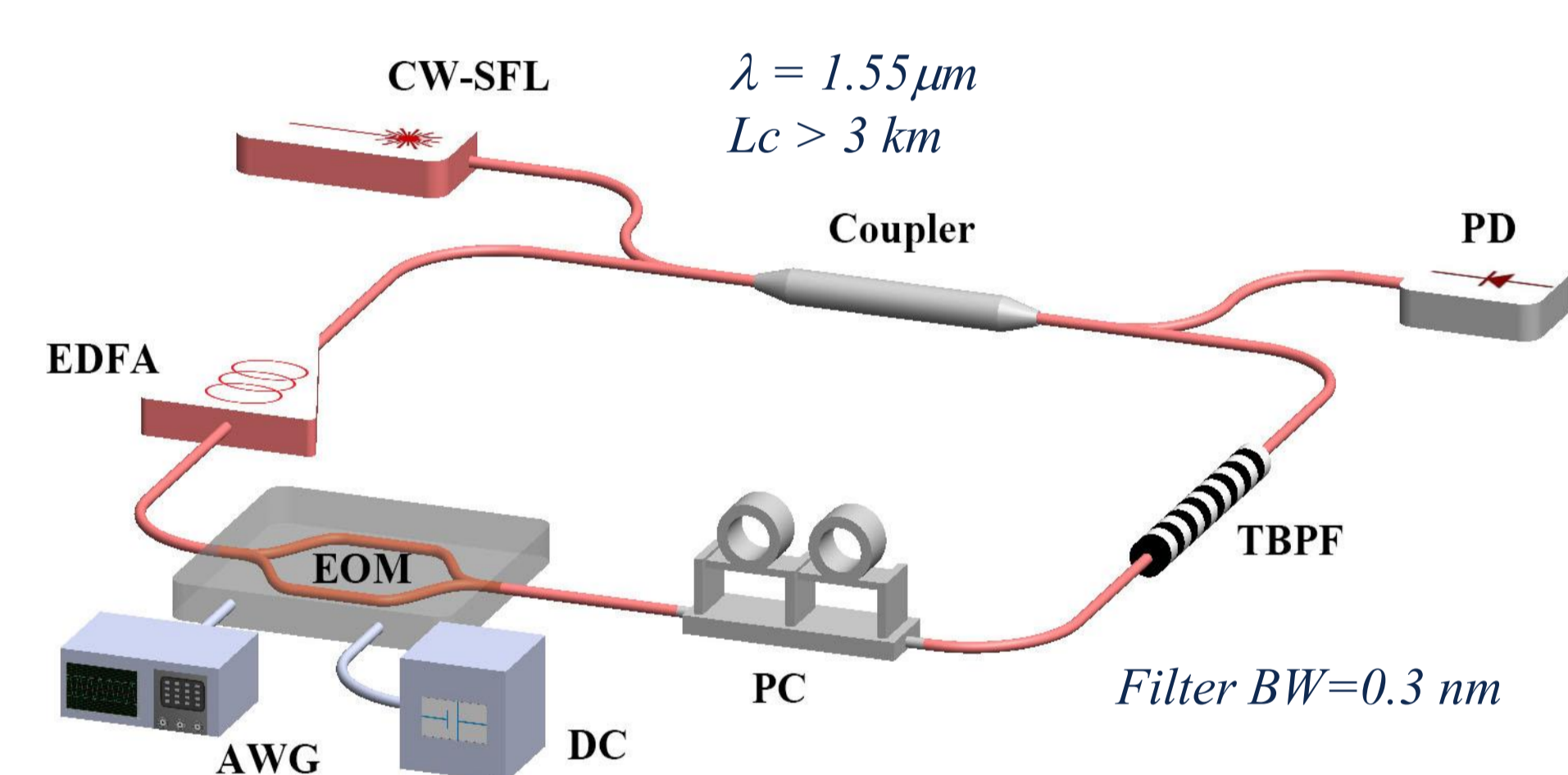
$$E_{out1}(t) = \left(\frac{t_{11} - \gamma(t_{11}t_{22} - t_{12}t_{21}) \sin \theta(t)}{1 - \gamma t_{22} \sin \theta(t)} \right) E_{in1}$$

→ Pulses for $\theta(t) \approx \pi/2$

Γ phase retardance
 Γ_m modulation depth



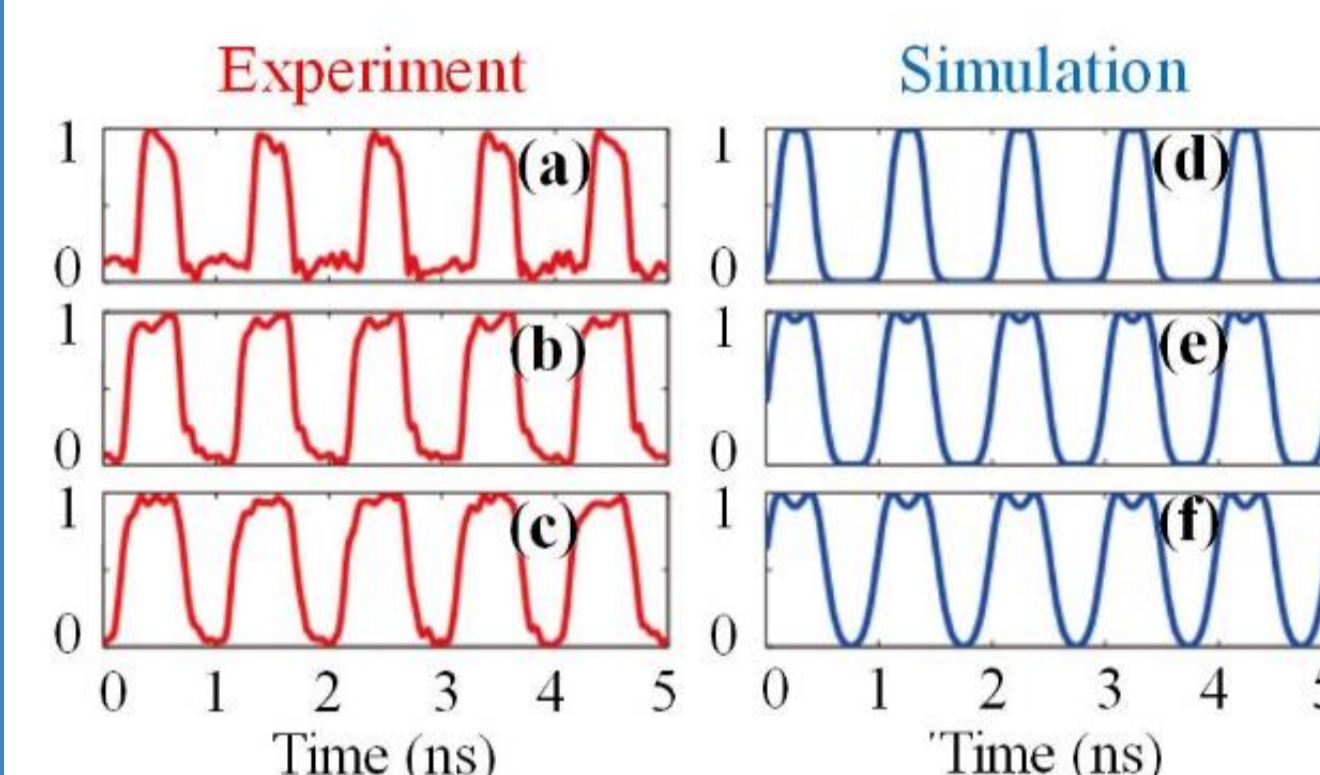
Experimental results



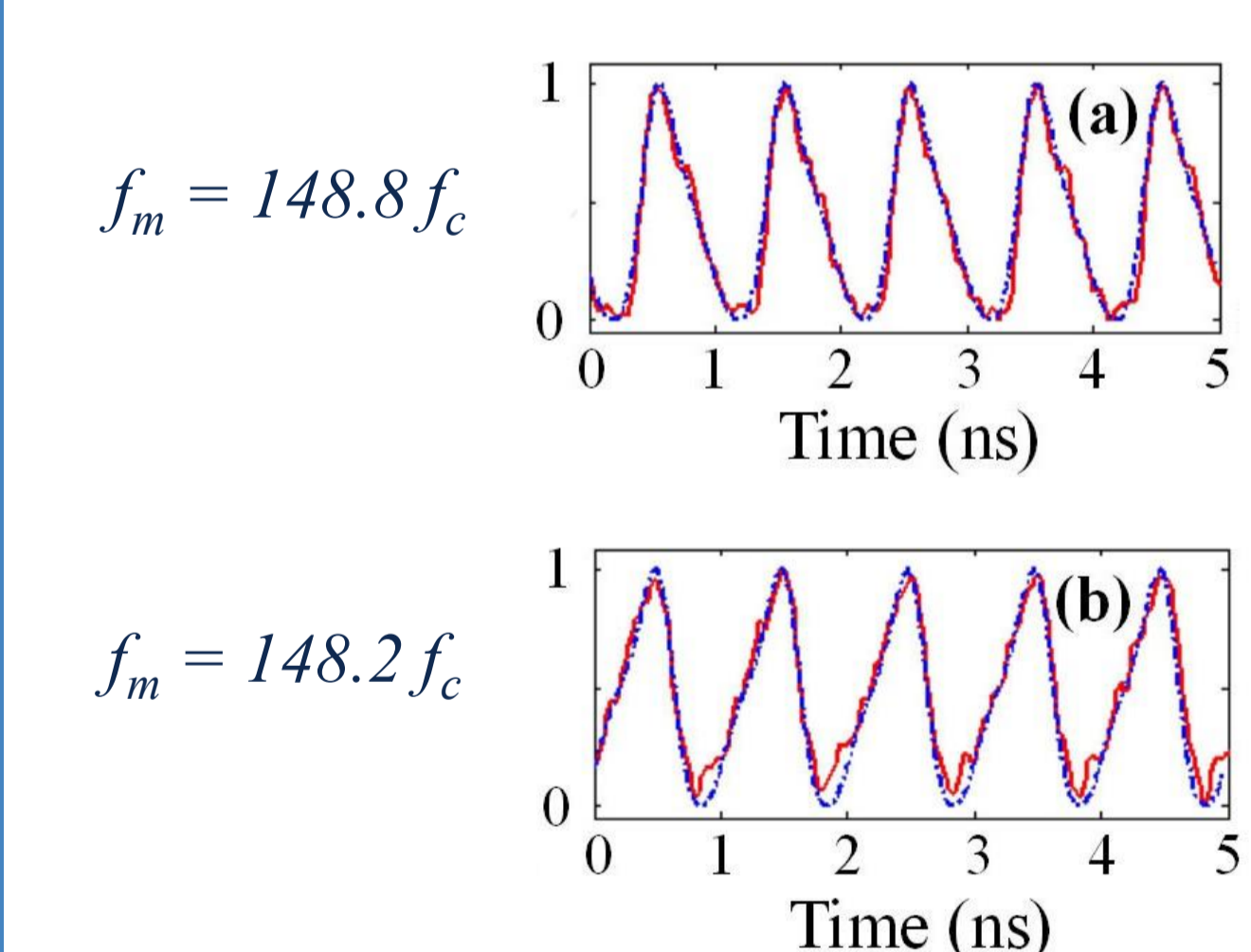
(H. Yang, Optics Express, submitted)

Waveform generation

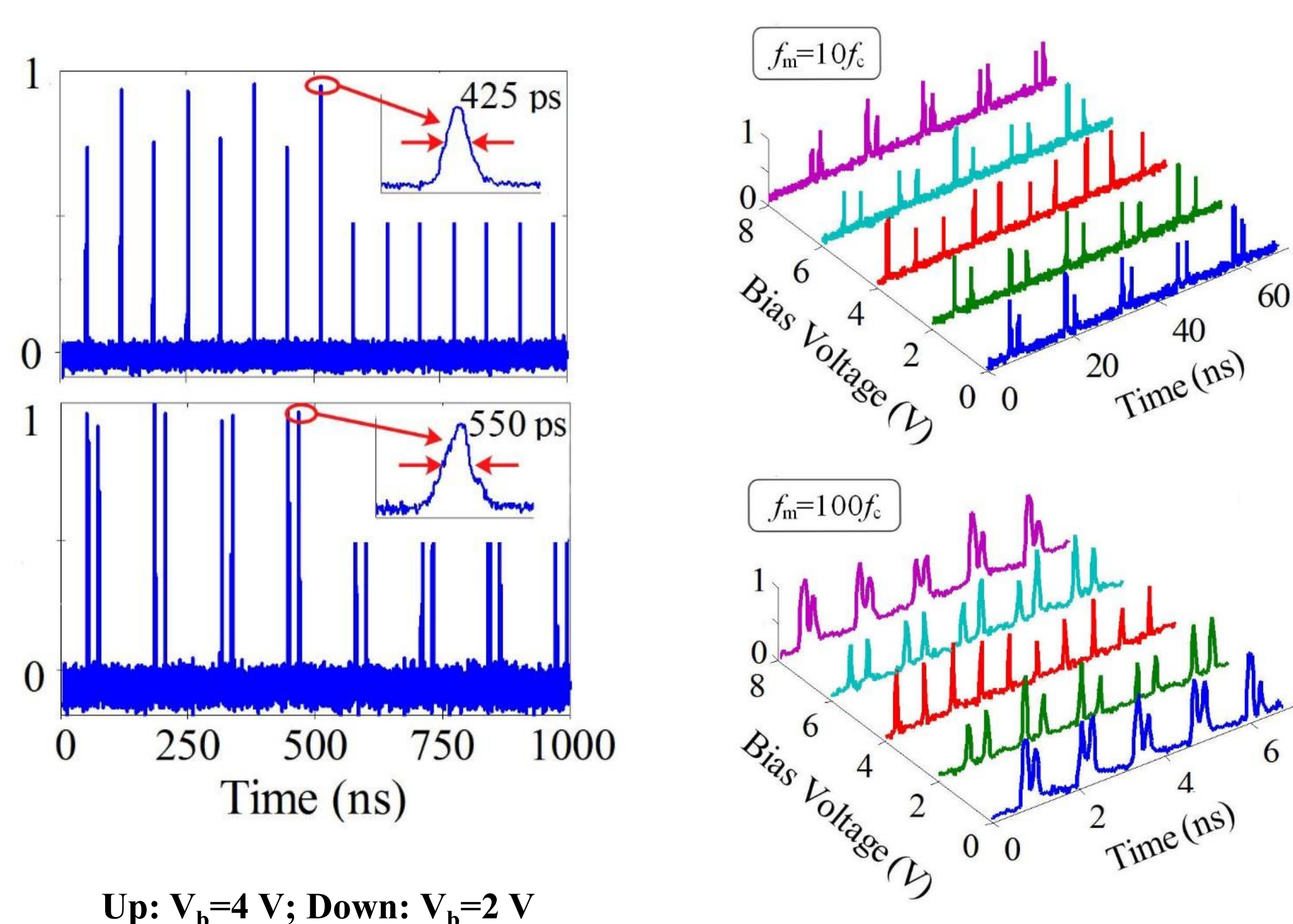
Rectangular shape



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

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- [4] L. Wang *et al*, CLEO Techn. Digest 2017
- [5] F. Tian, IEEE J. Lightwave technol. 2011
- [6] H.G. de Chatellus *et al*, Optica 2016