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

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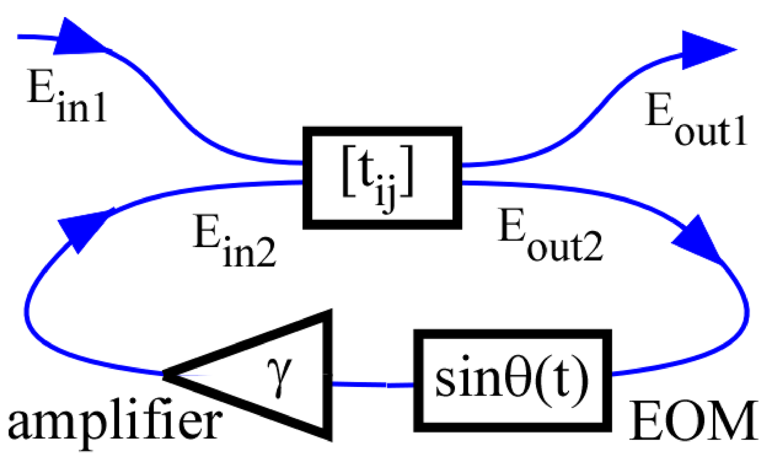
Introduction

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:

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

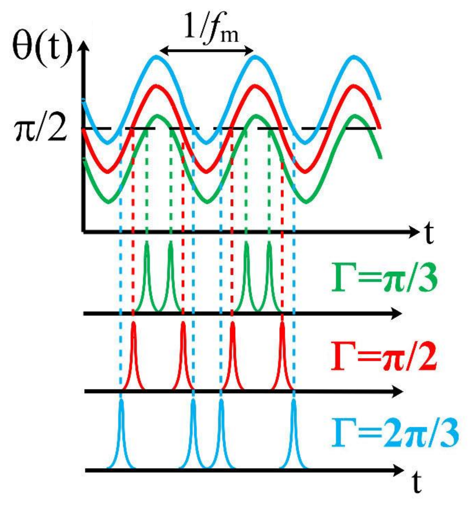
With modulation at f_m : $\theta(t)=\Gamma+\Gamma_m\sin(2\pi f_m t)$ — Γ phase retardance, Γ_m modulation depth

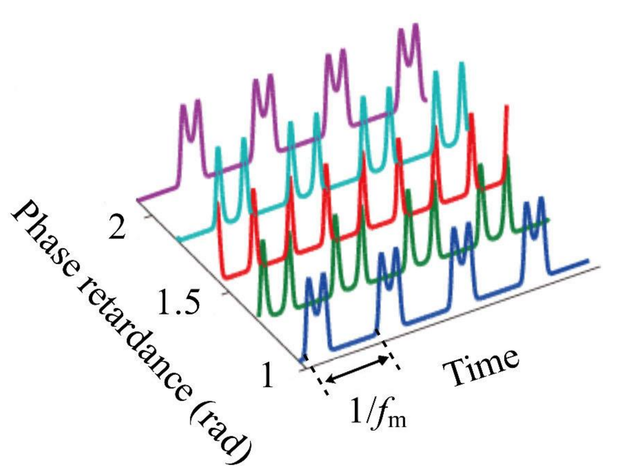
For integer Talbot condition [1-2]: $f_m=n/\tau$

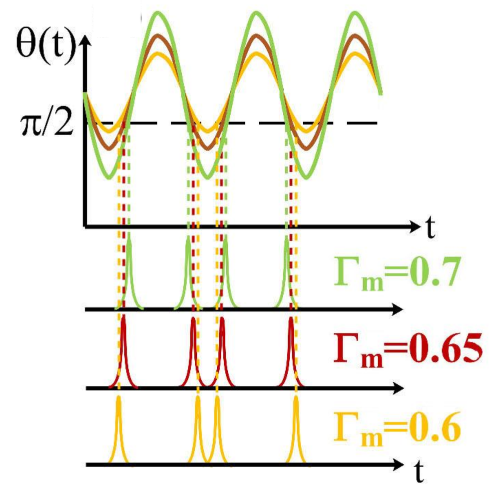
If $N \gg 1$ $$E_{out1}(t)=\frac{t_{11}-\gamma(t_{11}t_{22}-t_{12}t_{21})\sin\theta(t)}{1-\gamma t_{22}\sin\theta(t)}E_{in1}$$

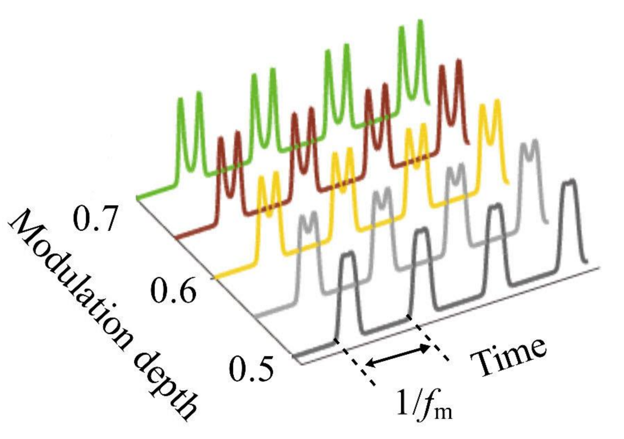
➡ E_{out1} pulsed for $\theta(t)\approx\pi/2$; 2 pulses per period $1/f_m$

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

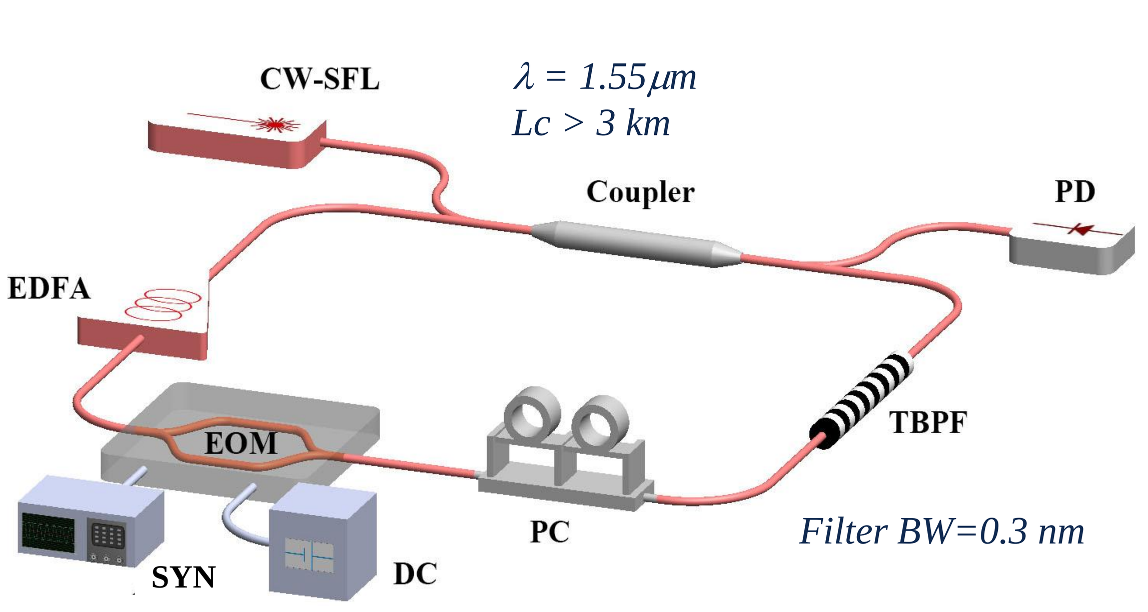


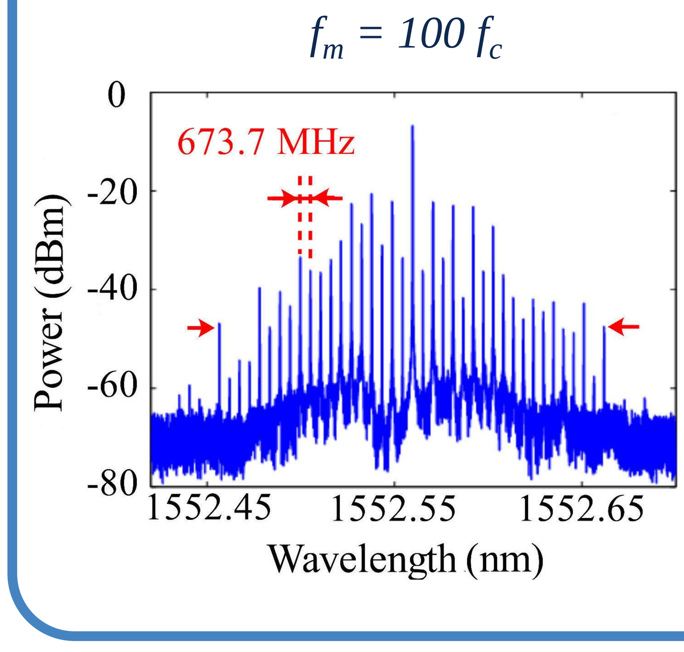


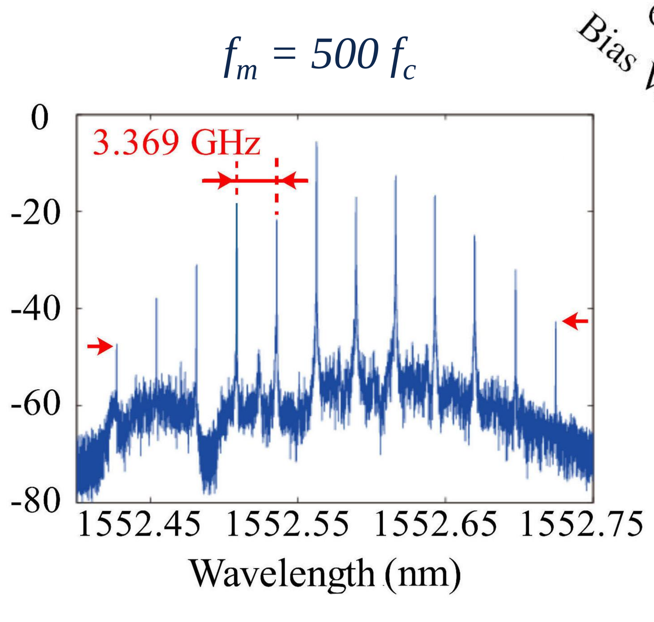


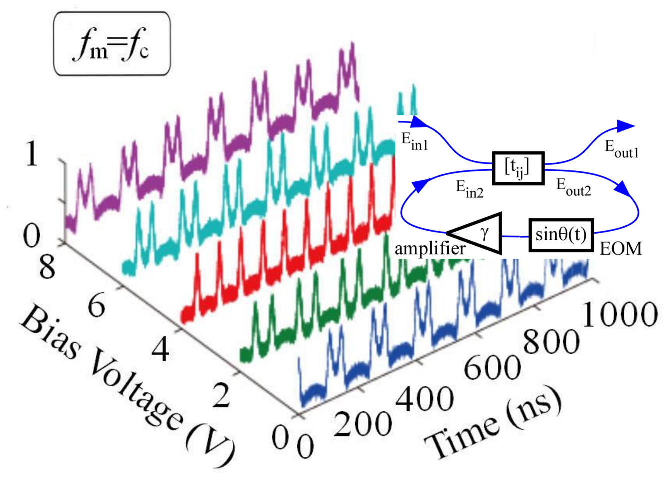


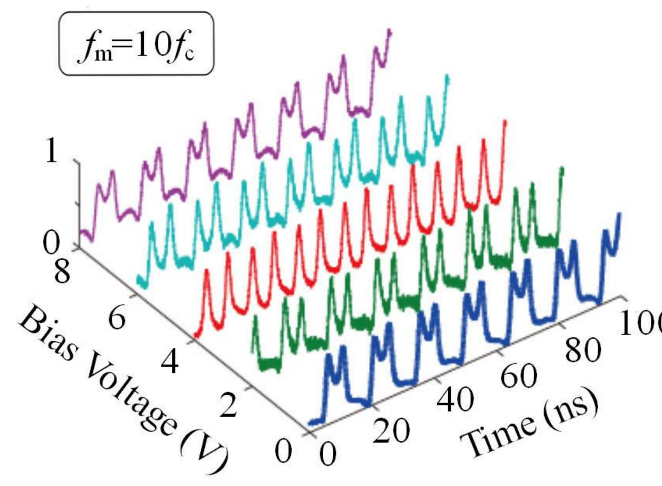
Experimental results

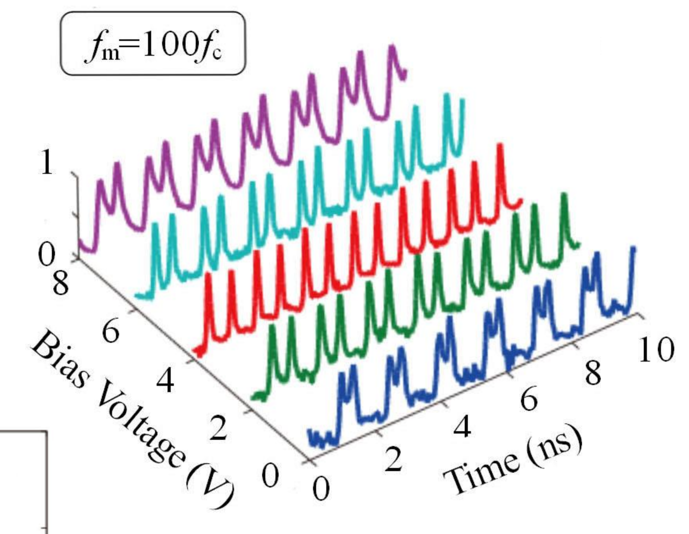


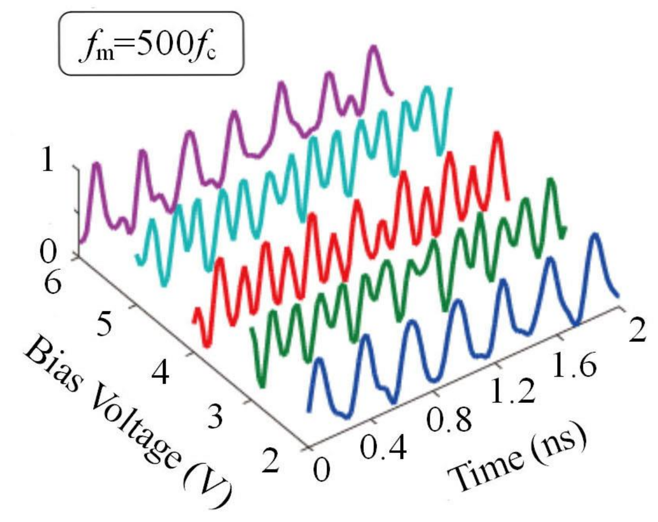










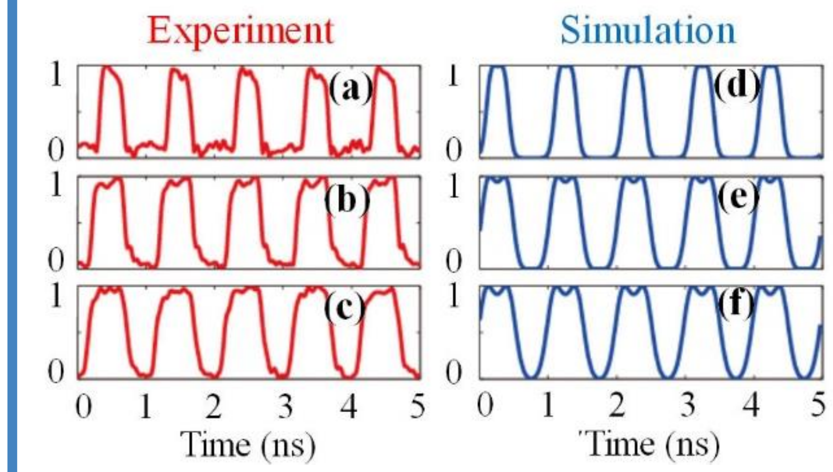


$1/\tau = f_c = 6.737$ MHz

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

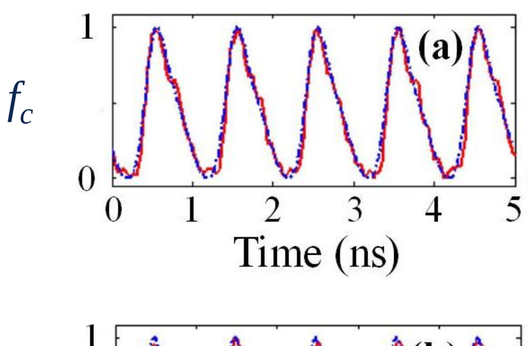
Waveform generation

Rectangular shape

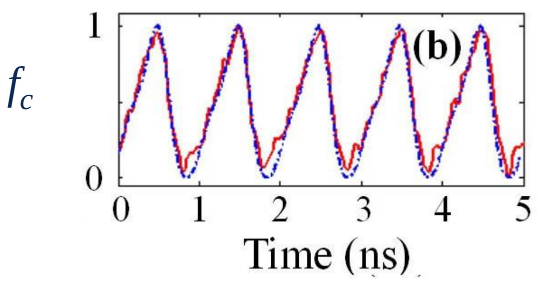


Sawtooth waveform

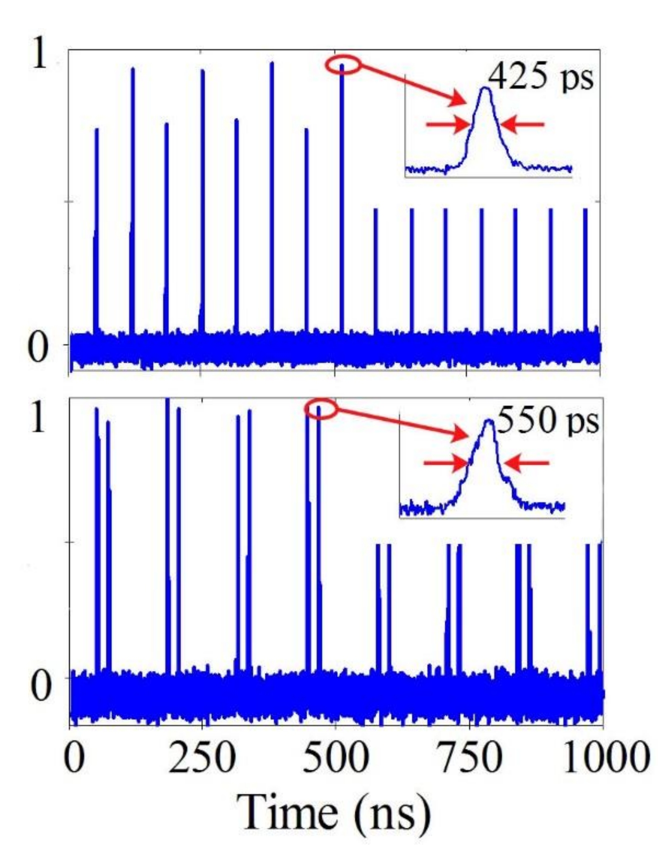
$f_m = 148.8\ f_c$



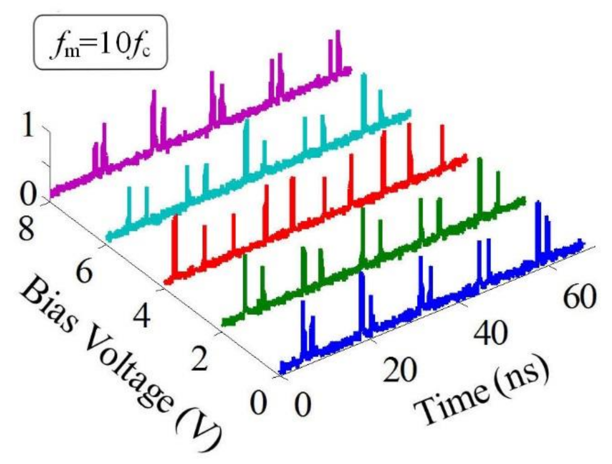
$f_m = 148.2\ f_c$

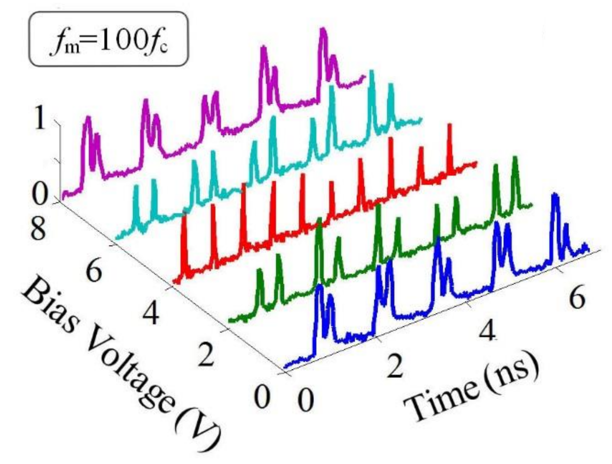


Mode-locked double-pulse regime



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 repletion rates

References

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[2] C. Schnébelin et al, CLEO 2017
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