

Generation of pump pulse trains by Gires-Tournois etalons for multicycle terahertz generation

Luis Nasi^{1,2}, Gergő Illés¹, János Hebling^{1,2,3}, György Tóth^{1,2}



¹Institute of Physics, University of Pécs, Pécs, 7624, Hungary

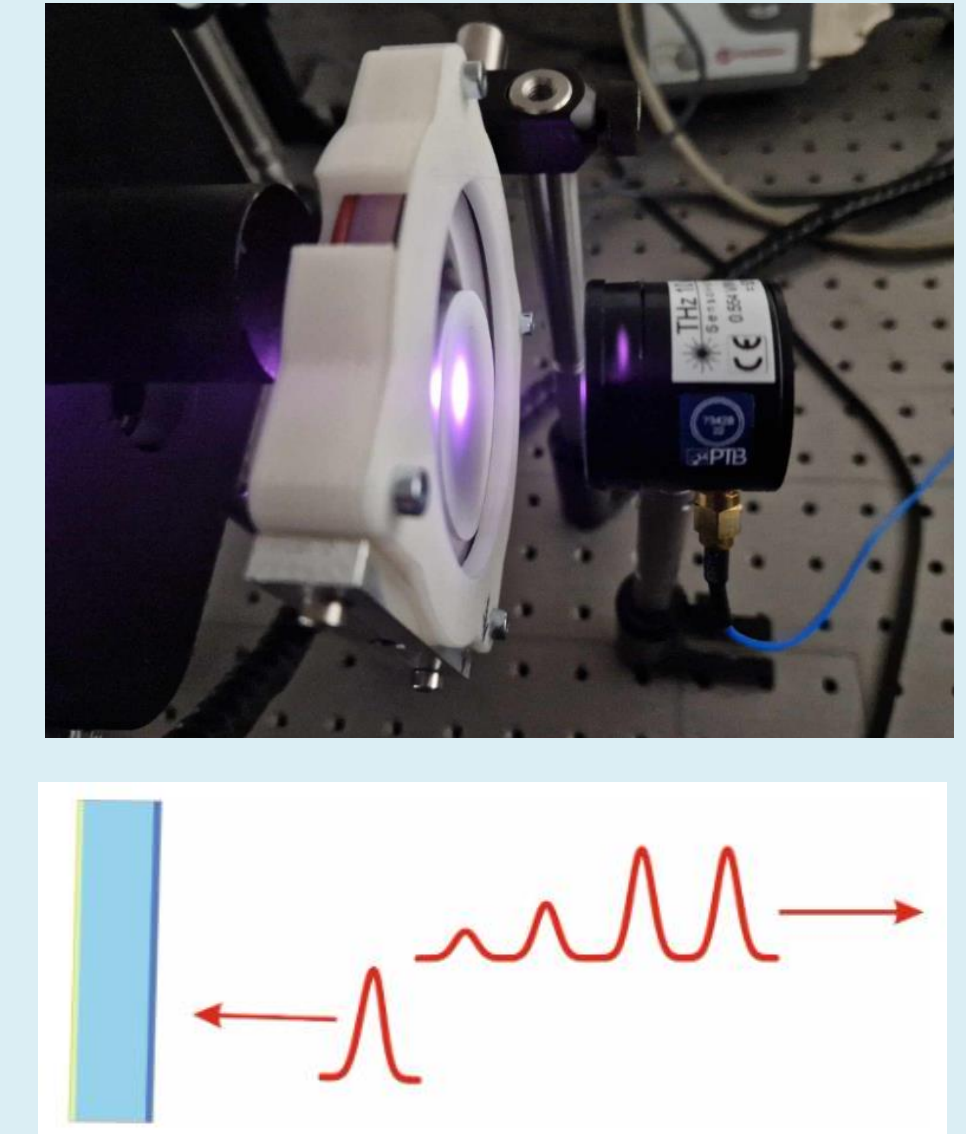
²Szentágotthai Research Center, University of Pécs, Pécs, 7624, Hungary

³HUN-REN-PTE High-Field THz Research Group, Pécs, 7624, Hungary



1. Introduction

Multicycle THz sources have recently become desirable in, among others, particle accelerators, as their longer pulse lengths provide for a higher interaction length. Optical rectification in periodically poled lithium niobate (PPLN) can be used [1,2] for THz generation, though this technique is bottlenecked by the small diameter restricted by poling technique. To overcome this, thin wafers of GaAs [3,4], and later of lithium niobate [5,6] rotated by 180 degrees with respect to each other have been used, creating so-called wafer stack (WS) structures. The THz frequency in periodic schemes is given by $\nu_0 = \frac{c}{\Lambda(n_{THz}^{ph}(\nu_0) - n_p^{gr})}$, where c is the speed of the light in vacuum, Λ is the PPLN or WS period length, n_{THz}^{ph} is the THz phase refractive index and n_p^{gr} is the pump group refractive index. Apart from pumping by a single ultrashort optical pulse, a pulse train can be used for both PPLN [7] and WS structures [8]. We examine this possibility and propose the use of Gires-Tournois etalons as an effective way to obtain pump pulse trains.



2. Pumping of wafer stacks by pulse trains

If a wafer stack of N_{WS} periods is pumped by a pulse train of N_p periods, the number of resulting THz cycles is given by $N_{cycl} = N_{WS} + N_p - 1$. For different numbers of WS pairs and pump pulses, the conversion efficiency was calculated.

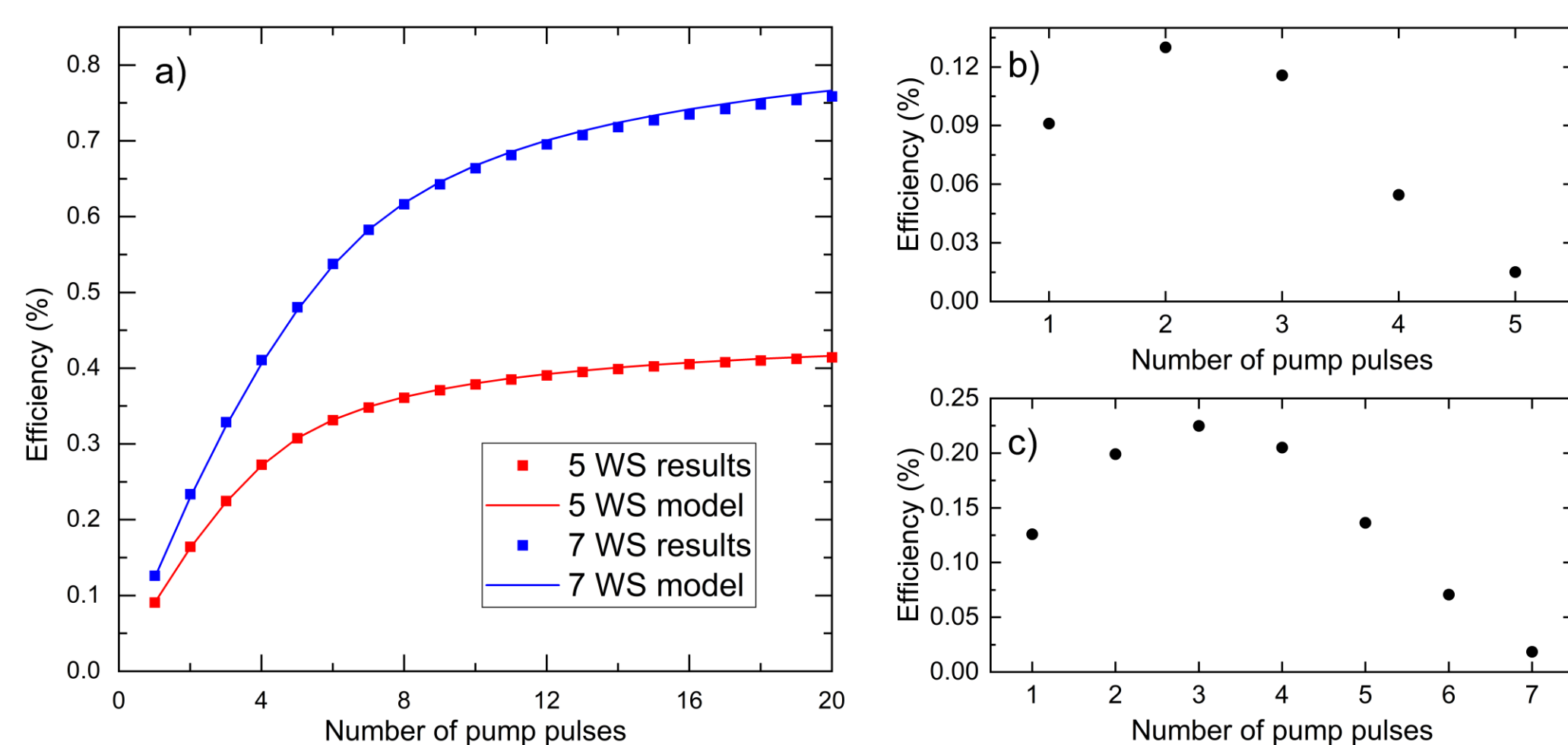


Fig. 1: a) THz conversion efficiencies as a function of the number of pump pulses, as obtained from simulations (squares) and from a simple model described below (line); b, c) Varying number of pulses so that the THz cycle number be 5 and 7, respectively.

A simple equation can give this efficiency as[8]:

$$\eta = \frac{W_{THz}}{W_{PS}} \approx \begin{cases} \frac{3N_{WS}N_p - N_p^2 + 1}{3} \cdot \eta_0, & \text{if } N_p \leq N_{WS}, \\ \frac{N_{WS}(3N_{WS}N_p - N_{WS}^2 + 1)}{3N_p} \cdot \eta_0, & \text{if } N_p \geq N_{WS}. \end{cases}$$

3. The Gires-Tournois etalon

The GT etalon consists of a partially reflective front surface, and a fully reflective back surface. The time delay introduced is given by

$$t = \frac{2d(n^2 - \sin^2 \alpha)}{cn\sqrt{1 - \sin^2 \alpha/n^2}},$$

where d is the thickness of the etalon, n its refractive index, and α the incidence angle. By having etalons of appropriate thicknesses, one can vary the delay, and also fine-tune it by changing the incidence angle.

4. THz generation

THz generation in wafer stacks pumped by the reflection from a GT etalon was simulated. First, the reflectivity was analyzed, for the case of having one etalon.

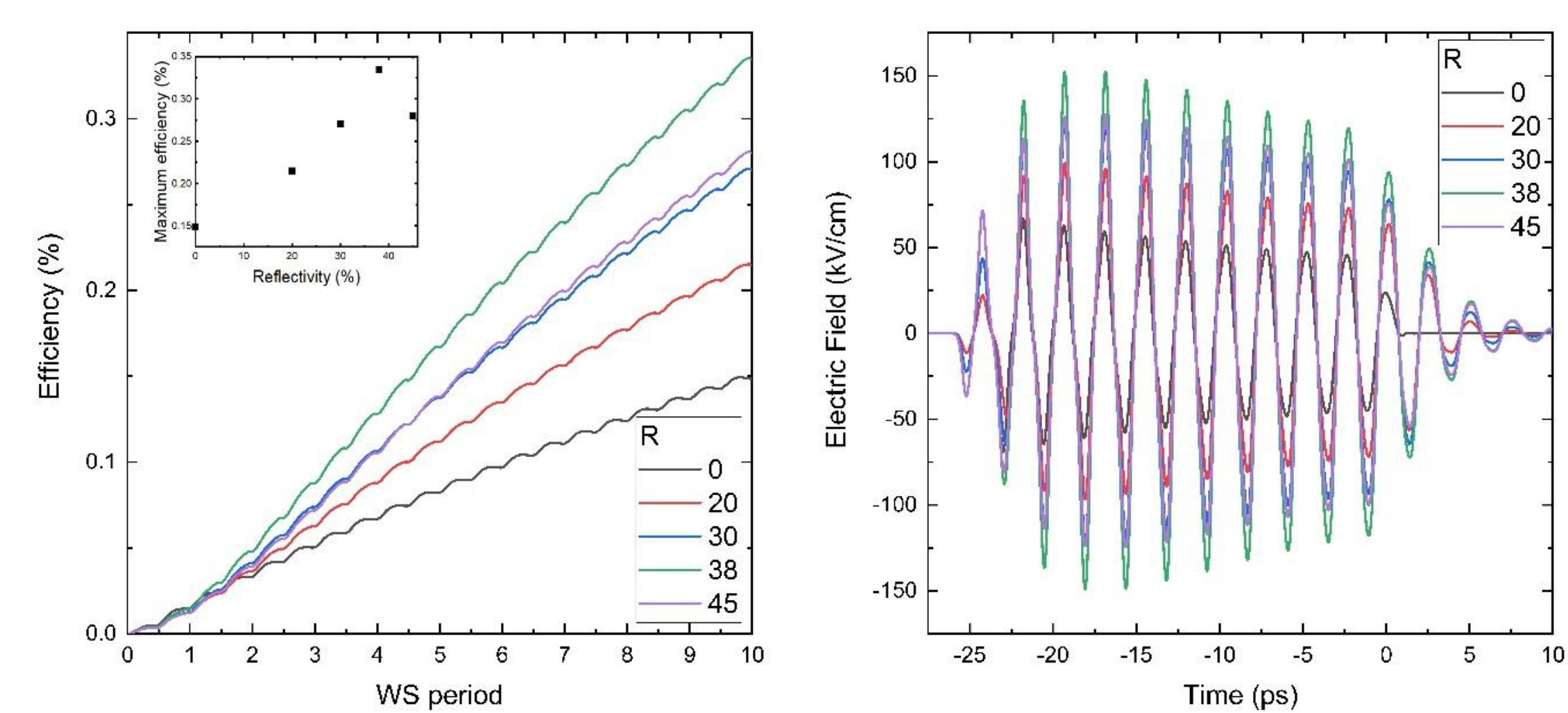


Fig. 2: THz generation efficiency (left) and the corresponding electric fields (right) for different reflectivity values.

As we can see, the 38% reflectivity is the most advantageous, which should come as no surprise, since that is when the first two reflections have equal intensities.

Next, the use of two cascaded GT etalons was investigated for three cases, when the second etalon has the same length as the first one, twice the length of the first one, and thrice the length of the first one. The resulting electric field becomes

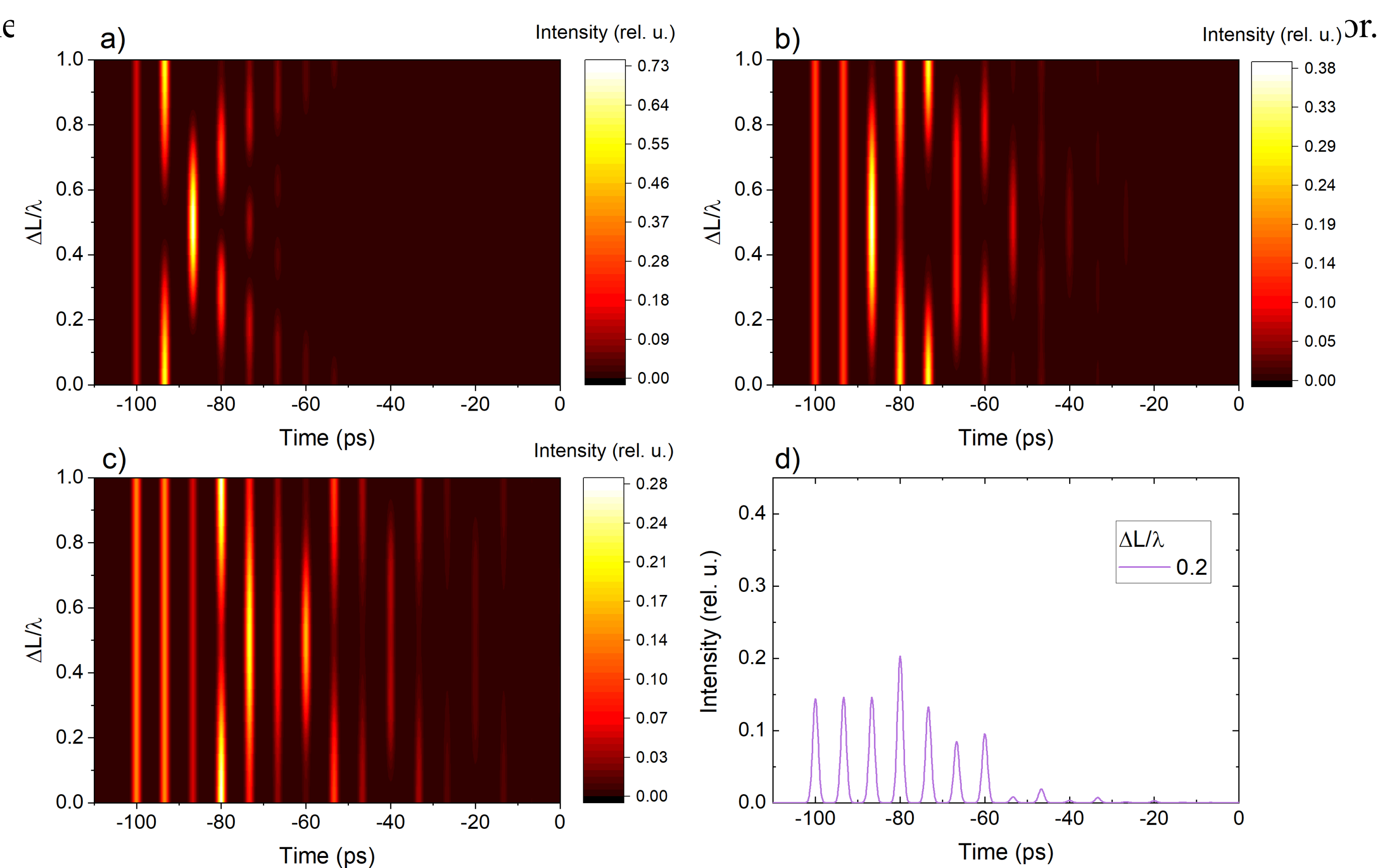


Fig. 3: Intensity distribution of the pulse trains created by two GT etalons, when the second is of the same, twice and thrice the length of the first one (cases a, b, c, respectively). d) Temporal intensity distribution for case b and $\Delta L/\lambda=0.2$ (the 0.2 case on the diagram above).

Of the cases above, the best one is when the second etalon introduces a delay twice as long as the first one. Furthermore, it was shown that the change in intensity due to phase differences, despite being significant, does not lead to vast differences in the THz generation efficiencies.

5. Conclusions

- Using pump pulse trains increases the efficiency of THz generation in PPLN/WS schemes
- GT etalons are an easy, practical way to create pump pulse trains
- These pump pulse trains can lead to an efficiency increase by more than double
- A second etalon can be cascaded, the width of which should be twice that of the first one. A third one not recommended.



6. References

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7. Acknowledgements

The project has been supported by Development and Innovation Fund of Hungary, financed under the TKP2021-EGA-17, OTKA-K 147409 funding scheme.