A THz-DRIVEN SPLIT RING RESONATOR FOR TEMPORAL CHARACTERIZATION OF FEMTOSECOND MeV ELECTRON BEAM

Y. Song, K. Fan, C.-Y. Tsai
Huazhong University of Science and Technology, Wuhan, China

Abstract

The use of THz-driven split ring resonator (SRR) as a streak camera for sub-ps bunch length measurement has been proposed for a few years. Since then, the feasibility of such a method has been experimentally demonstrated for both keV and MeV electron beam. The structural dimensions of SRR has a substantial impact on the resonance frequency, the field enhancement factor and the interaction region of the streaking field, eventually determining the temporal resolution of the bunch length measurement. Here we quantitively discuss the dependence of the streaking field on the structural dimensions of SRR. Combining with an analytical streaking model, we propose a method to optimize the structural dimensions of SRR such that the finest temporal resolution is achieved with given THz pulse.

Introduction

Split-ring resonator (SRR) is a sub-wavelength structure that focuses the incident THz radiation into the gap region, and the enhanced streaking field thus emerges in the gap. The streaking field provided by SRR is potentially up to GV/m level and the frequency is about two orders higher than the RF deflector. Moreover, since the THz radiation is originated from the laser system, the streaking field is tightly synchronized to the laser system. Experiments have been demonstrated for the temporal characterization of both keV and MeV electron beam. The experiment results indicate that SRR can provide sub-10 fs temporal resolution for bunch length measurement and sub-fs accuracy for TOA determination.

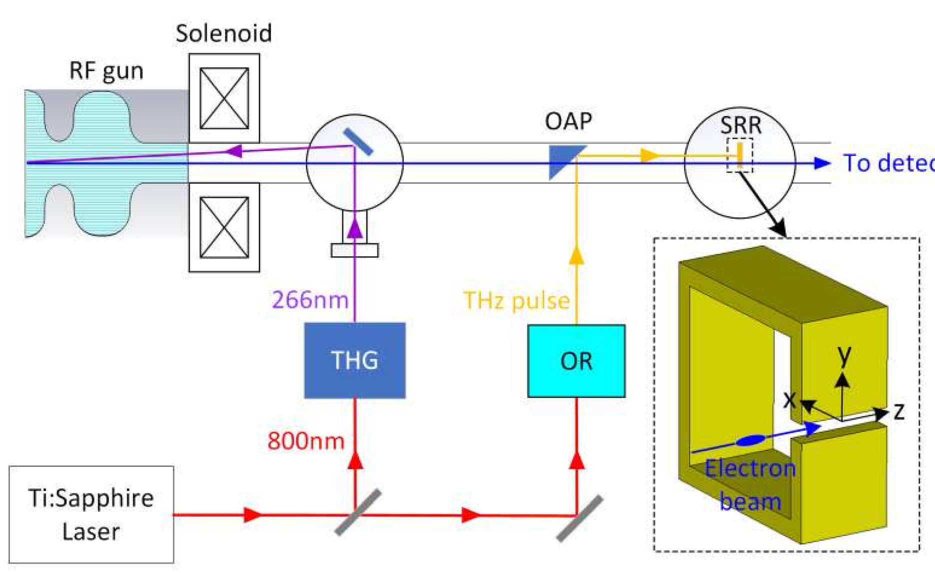


Figure 1: Schematic of the SRR based streak camera.

Temporal Resolution

The temporal resolution of the bunch length measurement is inversely proportional to

$$\tau_s \propto \frac{1}{\omega E_{\max} \int_{-\infty}^{\infty} A(\beta ct)\cos(\omega t)\,dt}.$$

We define a normalized parameter F as a alternative measure for temporal resolution.

$$F = f_0 C_{enh} T_e$$

f_0 is the resonance frequency of SRR. C_{enh} is the field enhancement factor which equals to the ratio of the peak streaking field on the THz driving field, T_{e} is the equivalent interaction time. Higher F indicates finer resolution.

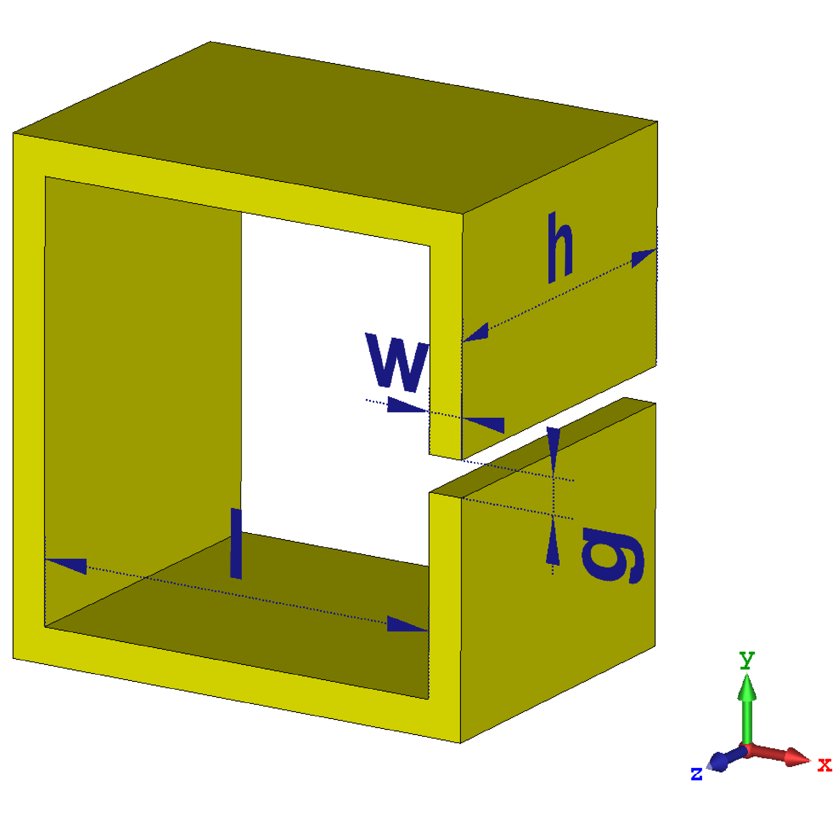
$$T_e = \int_{-\infty}^{\infty} A(\beta ct)\cos(2\pi f_0 t)\,dt$$

Square SRR Model

The square SRR model we use for structural optimization is shown in the right.

Here we use four dimensions (l, h, g, w) to describe a square SRR.

The material of this SRR is copper.



Simulation Results

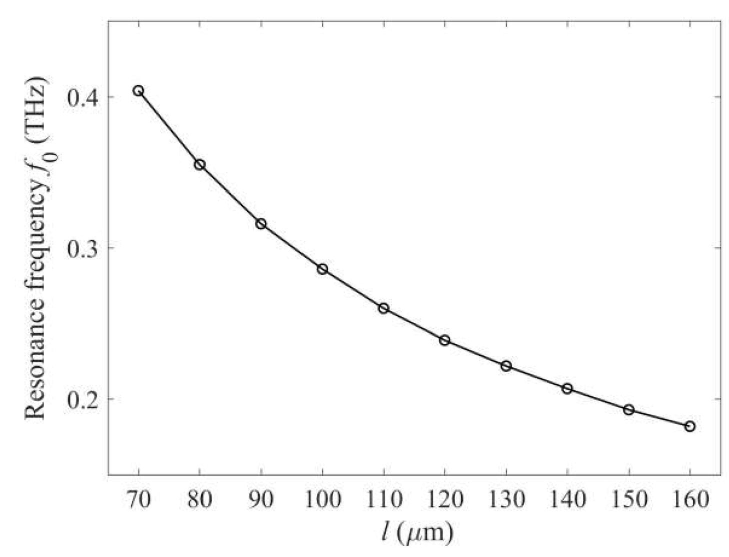


Figure 2: Resonance frequency as a function of l.

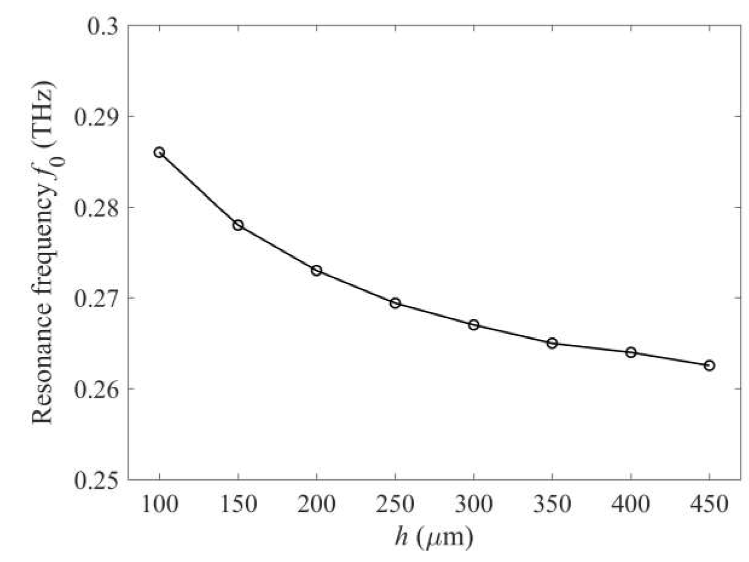


Figure 6: Resonance frequency as a function of h.

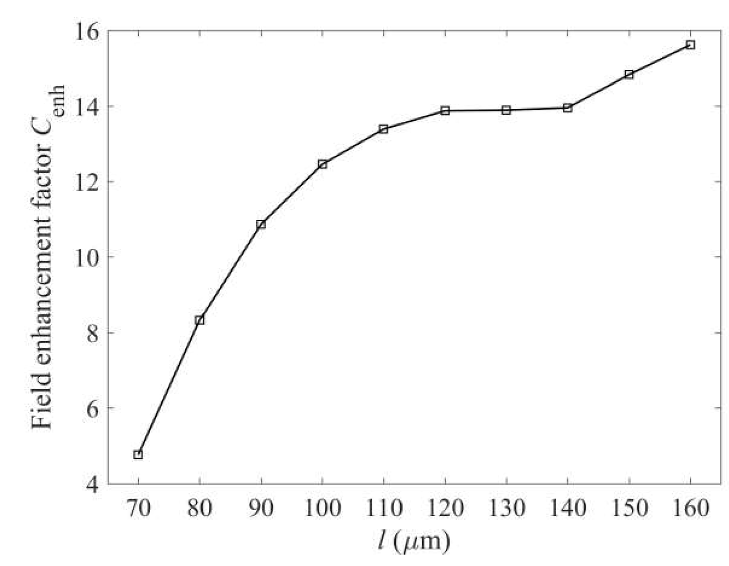


Figure 3: Field enhancement factor as a function of l.

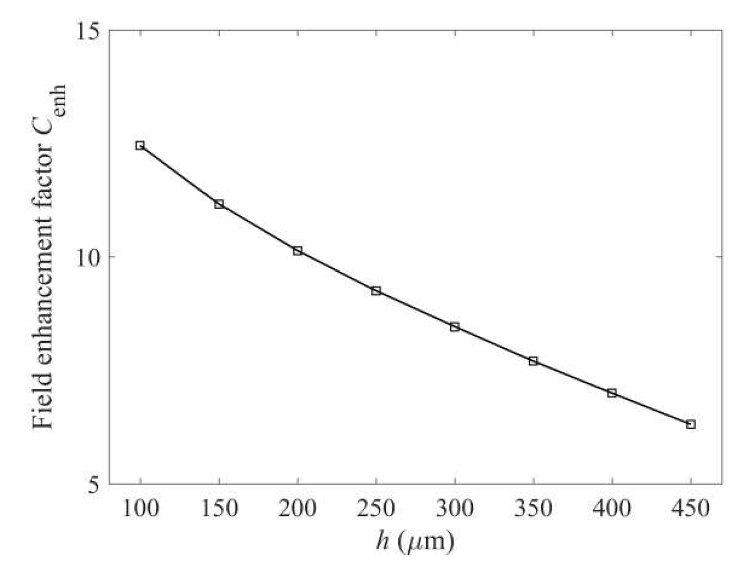


Figure 7: Field enhancement factor as a function of h.

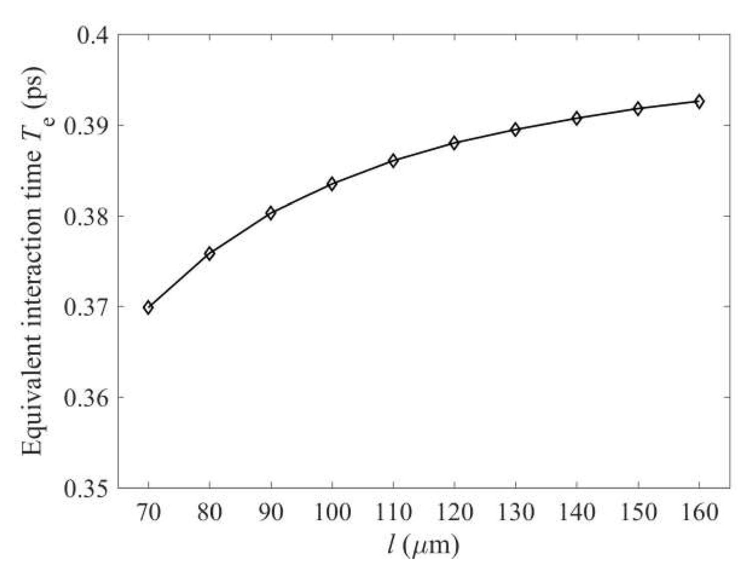


Figure 4: Equivalent interaction time as a function of l.

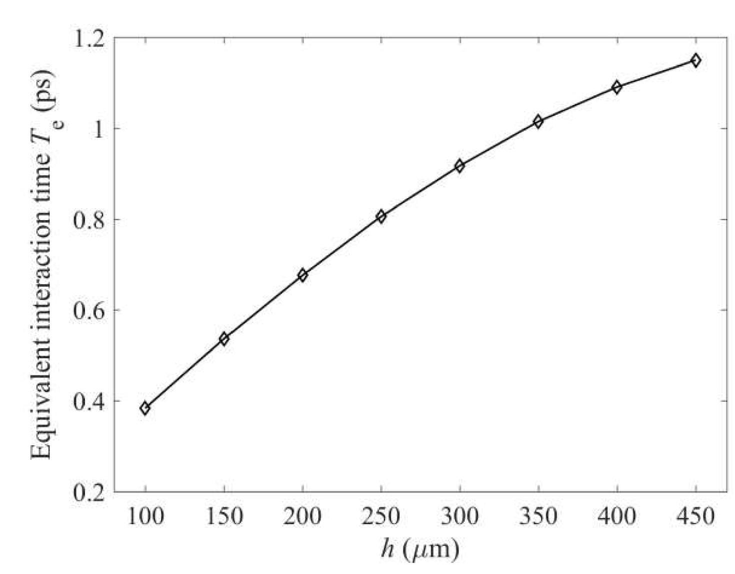


Figure 8: Equivalent interaction time as a function of h.

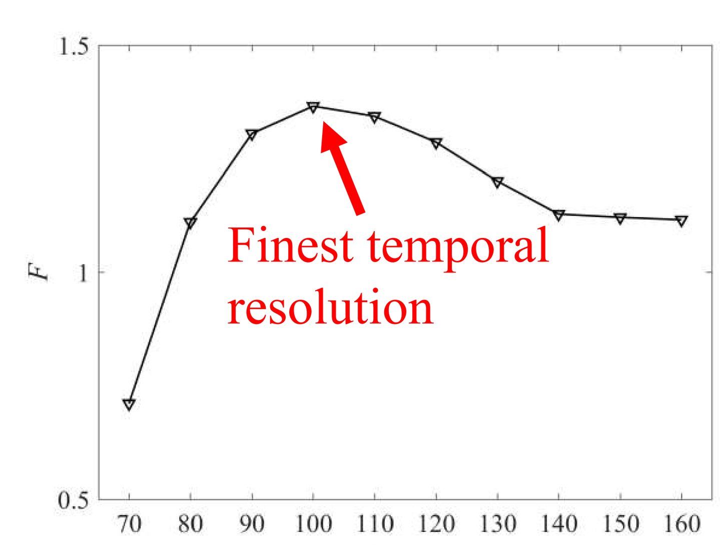


Figure 5: Parameter F as a function of l.

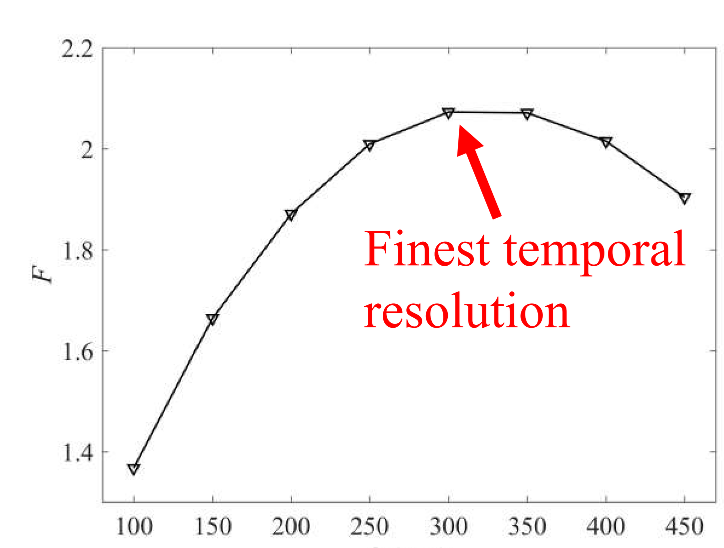


Figure 9: Parameter F as a function of h.

Summary

We focus on the l and h dimension of SRR. We find that SRR with larger l has a larger field enhancement factor while the resonance frequency is smaller. This property indicates that an optimal l exists that produces the smallest temporal resolution. Meanwhile, if we increase h, the equivalent interaction time increases as well, but the resonance frequency and field enhancement factor both drop. Again, an optimal h is found to obtain the smallest temporal resolution. With the optimized dimension, the square SRR can provide sub-10 fs temporal resolution with 50 MV/m peak streak field.