67th ICFA Advanced Beam Dynamics Workshop on Future Light Sources (FLS 2023)

Heating load and radiation pulse of Corrugated Structure at SHINE Facility

Junjie Guo[1], Duan Gu[2], Zhen Wang[2], Meng Zhang[2], Qiang Gu[2], Haixiao Deng[2]

guojj@zjlab.ac.cn

[1]Shanghai Optoelectronic Science and Technology Innovation Center, Shanghai 201210, China.

[2]Shanghai Advanced Research Institute, Chinese Academy of Sciences, Shanghai 201210, China.

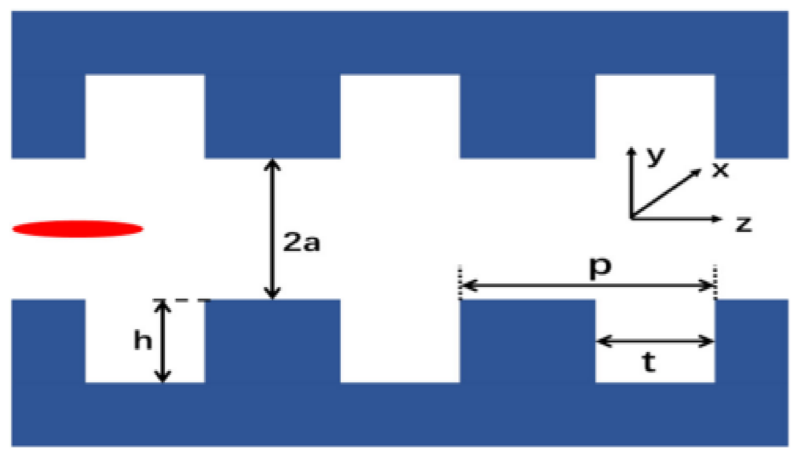
Abstract

Corrugated structure modules are being proposed for installation after the end of the linac and before the undulator regions of SHINE facility, where it has been used for energy chirp control or as a fast kicker for two color operation of the FEL.When ultra-relativistic bunch of electrons passing through corrugated structure will generate strong wakefield, we find most of the wake power lost by the beam is radiated out to the sides of the corrugated structure in the form of THz waves, and the remaining part casue Joule heating load on the corrugated structure wall. In this paper, we estimate the Joule power loss and Terahertz radiation power of the corrugated structure in SHINE facility.

Corrugated Structure of Shine Facility

Structural Parameter of corrugated structure	Value
Plate length, L (m)	2
Gap, a (mm)	0.7 ~ 30
Depth, h (mm)	0.5±0.025
Period, p (mm)	0.5±0.025
Longitudinal gap, t (mm)	0.25±0.013
Width, w(mm)	12.7±0.025
W/2a	9.0714~0.2117

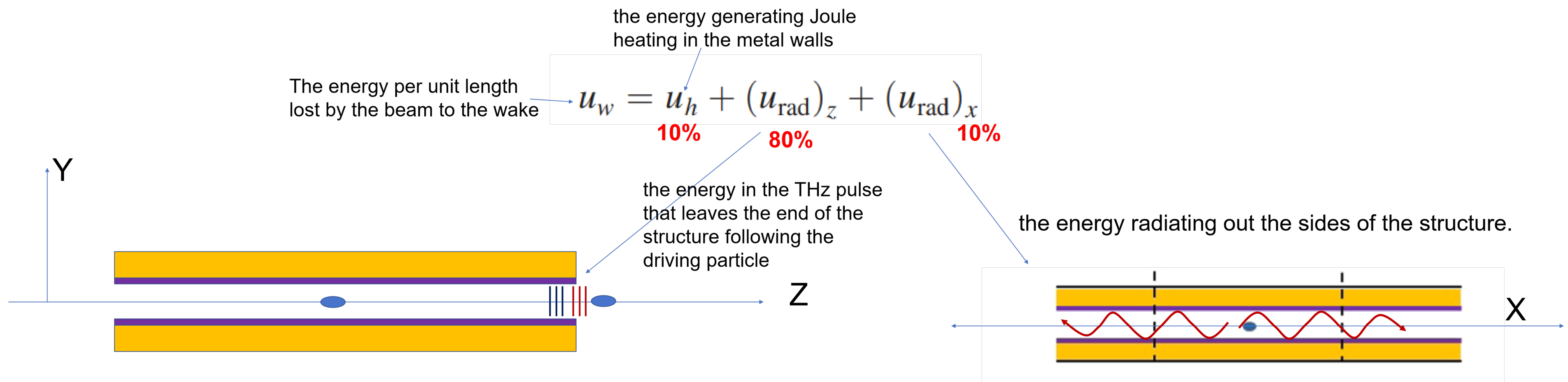
Beam Parameters upon entering corrugated structure	Value
Energy, E (GeV)	8
Charge per bunch, Q (PC)	100
Beam current, I (kA)	1.5
Bunch length (RMS), $\sigma(\mu m)$	5



Structural Parameter and Beam Parameters upon entering SHINE corrugated structure (left table), Schematic view of the SHINE corrugated structure (right plot).

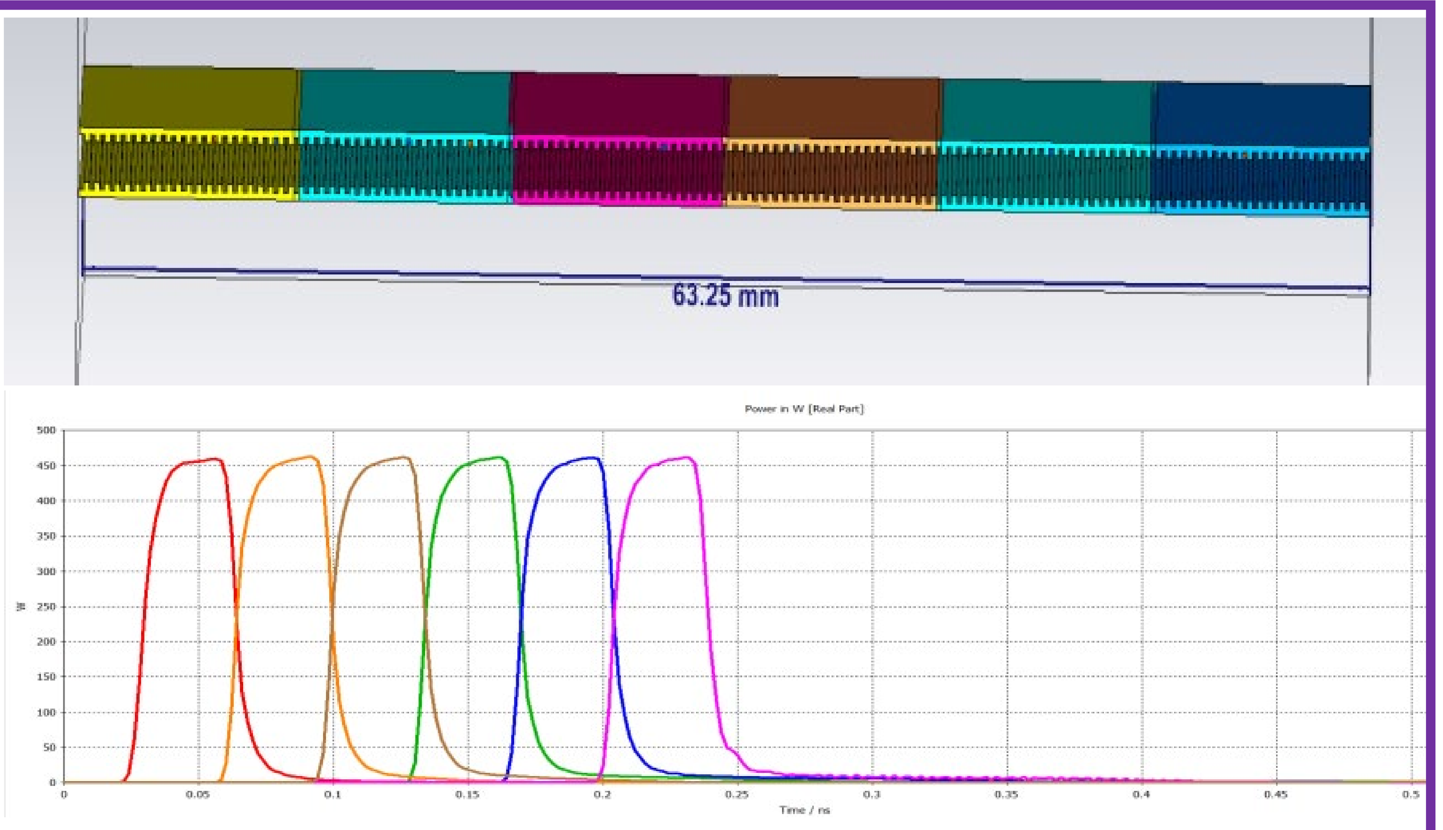
The distribution of wake power caused by the beam through the Corrugated Structure

$$u_w = u_h + (u_{\mathrm{rad}})_z + (u_{\mathrm{rad}})_x$$



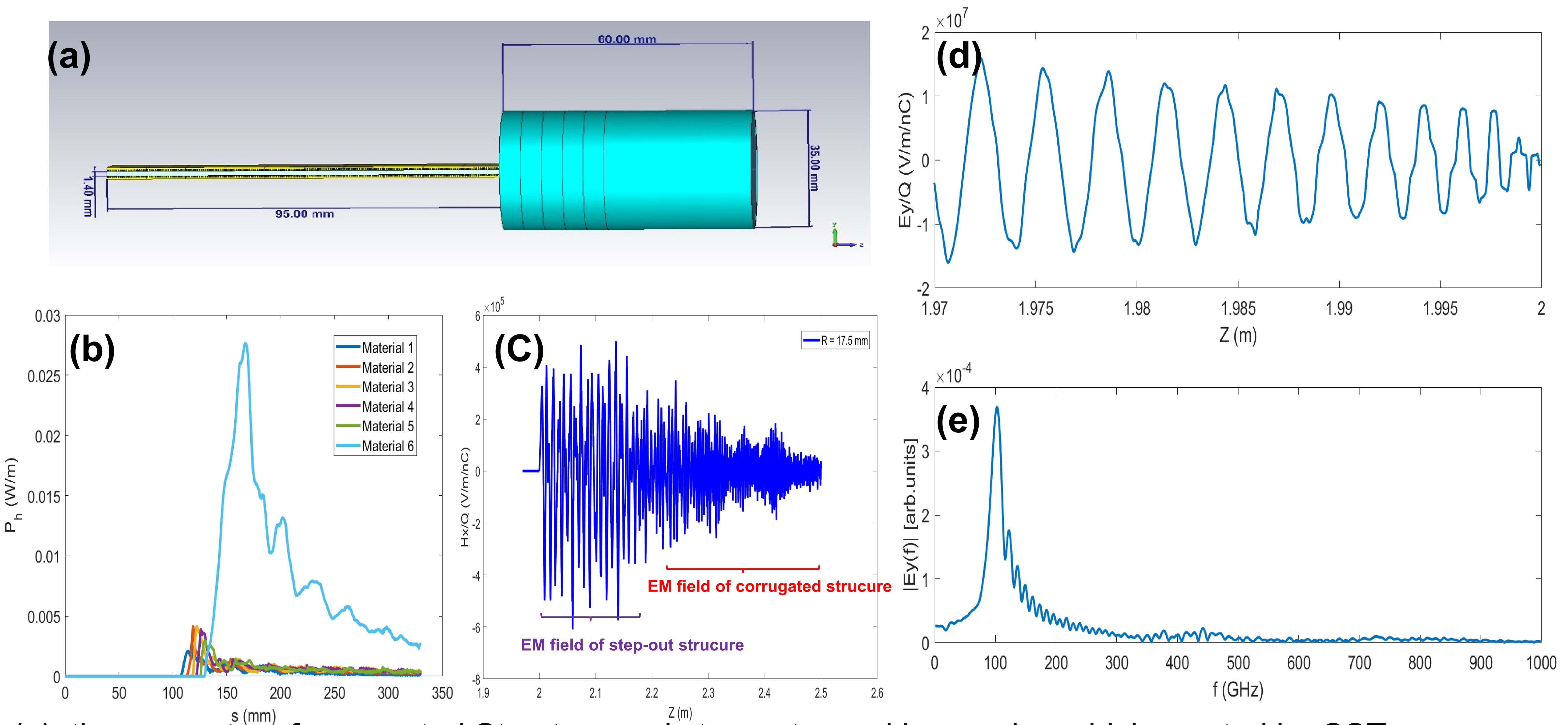
Joule Heating of Corrugated Structure at Shine Facility

Parameter	beam passing through the corrugated structure on axis, gap = 0.7 mm	beam near one plate, a distance from the near wall of b=0.25 mm
bunch charge, (pC)	100	100
Repetition frequency, MHz	1	1
Bunch length (RMS), $\sigma(mm)$	0.005	0.005
Loss factor (KV/pC/m)	20.44	58.067
total wake power lost by the beam, (W/m)	204.4073	580.67
Joule Heating of Corrugated Structure, (W/m)	20.44	31.93



Uniform distribution of heat load inside the corrugated structure

A radiation pulse generated by corrugated Structure at SHINE Facility



(a): the geometry of corrugated Structure and step-out round beam pipe which created by CST;
(b):Joule power calculations of (a)-plot geometry obtained by CST time-domain simulation;
ECHO simulation : (c):Hx field calculations (a)-plot geometry; (d):The radial electric field Ey at y = 0.7 mm at a monitor located at the downstream end of corrugated strucure as function of time t;
(e)The absolute value of the Fourier transform of this function, Ey, as function of frequency f .

Conclusion

We have performed heating load calculations and radiation pulse for the SHINE corrugated structure in this paper. We find that 204 W/m (80%) most of the wake power lost by the beam is radiated out to the sides of SHINE corrugated structure, and only 20.4 W/m (10%) a small part of the power caused heating load of metal wall. Most of the wake power is radiated downstream along the Z-axis of corrugated structure in the form of pulse, which can cause severe downstream heating load effect. Calculations and analyses show that the radiation pulses generated by the corrugated structure will spread on the walls of the 35 mm radius circular beam pipe 30 ~50 cm from the exit of the pleated structure, so additional cooling water pipes are required. At the same time, in order to avoid damage to downstream components from radiation pulses, the photon absorber might be considered to be mounted to the downstream.