Numerical Studies of Geometric Impedance at NSLS-II with GdfidL and ECHO3D

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Introduction

Performance of low-emittance light sources is limited by

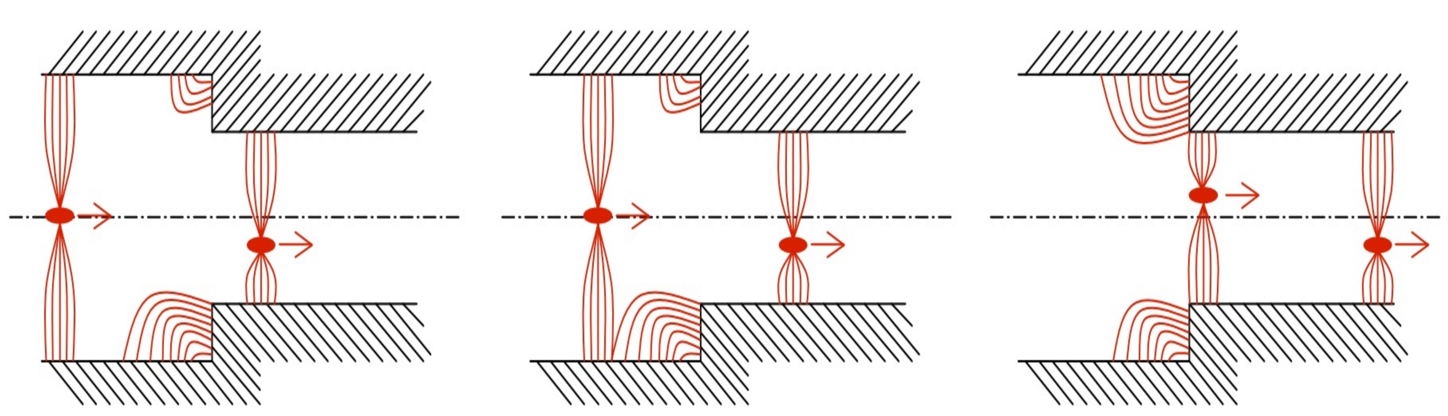
- The short-range wakefields or impedance, especially beam-induced heating of the vacuum chamber components

Presented study discuss

- Cross-checking of two electromagnetic solvers, GdfidL and ECHO3D
- Convergence studies of geometric impedance in the NSLS-II flange absorber and in the bellows

Basic Definitions

Wake function: electromagnetic response of a beam pipe/chamber/object to a charge pulse



Ref: https://uspas.fnal.gov/materials/09UNM/Unit_6_Lecture_14_Wakefileds.pdf

Impedance: Fourier transform of the wake functions

Loss factor: estimates the beam-induced heating

$$k_{\text{loss}} = \frac{1}{\pi}\int_0^\infty d\omega\ \text{ReZ}_{\|}(\omega)e^{-\omega^2\sigma_b^2/c^2}$$

$Z_{\|}$: longitudinal impedance, σ_b: bunch length

Simulation Tools

Parameter	GdfidL	ECHO3D
Input geometry	STL file, Text description of the device	STL file
Numerical method	Yee's finite-difference time-domain method, window-wake technique	"Transversal-electric/transversal-magnetic" splitting of the field components in time
Mesh size	$\Delta \le \sigma_s/15$ Equal mesh in longitudinal and transverse plan	$\Delta \le \sigma_s/5$ Good accuracy is achievable with coarse transverse mesh
Parallelization	Parallelized for multi-core clusters	Thread parallelized with OPENMI

Convergence Studies

NSLS-II Flange Absorber:

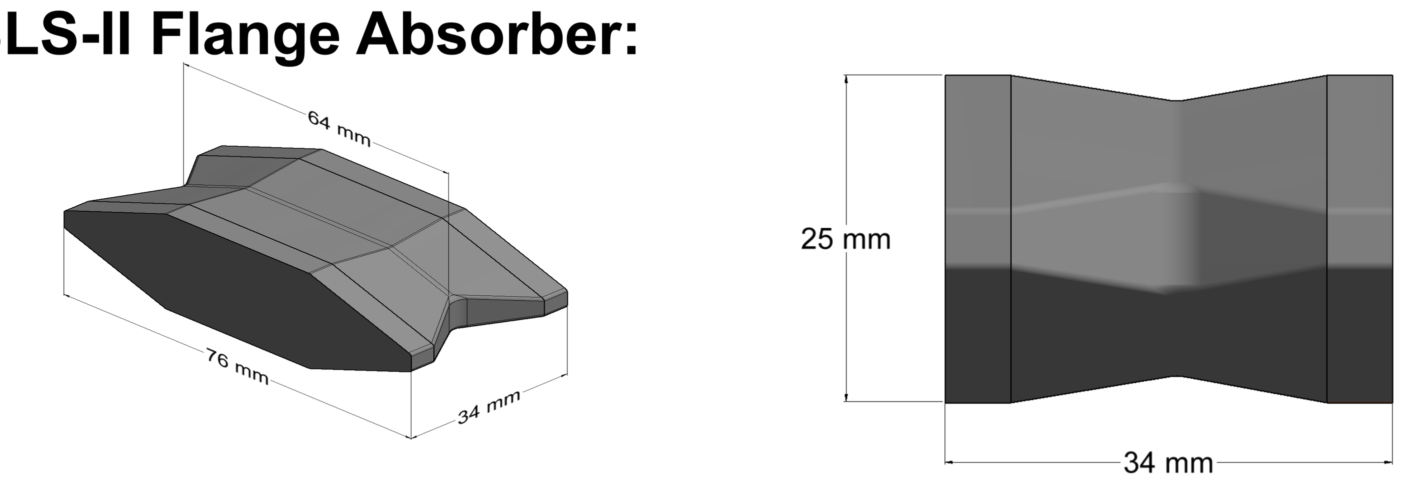


Fig.1: Schematics of the NSLS-II flange absorber.

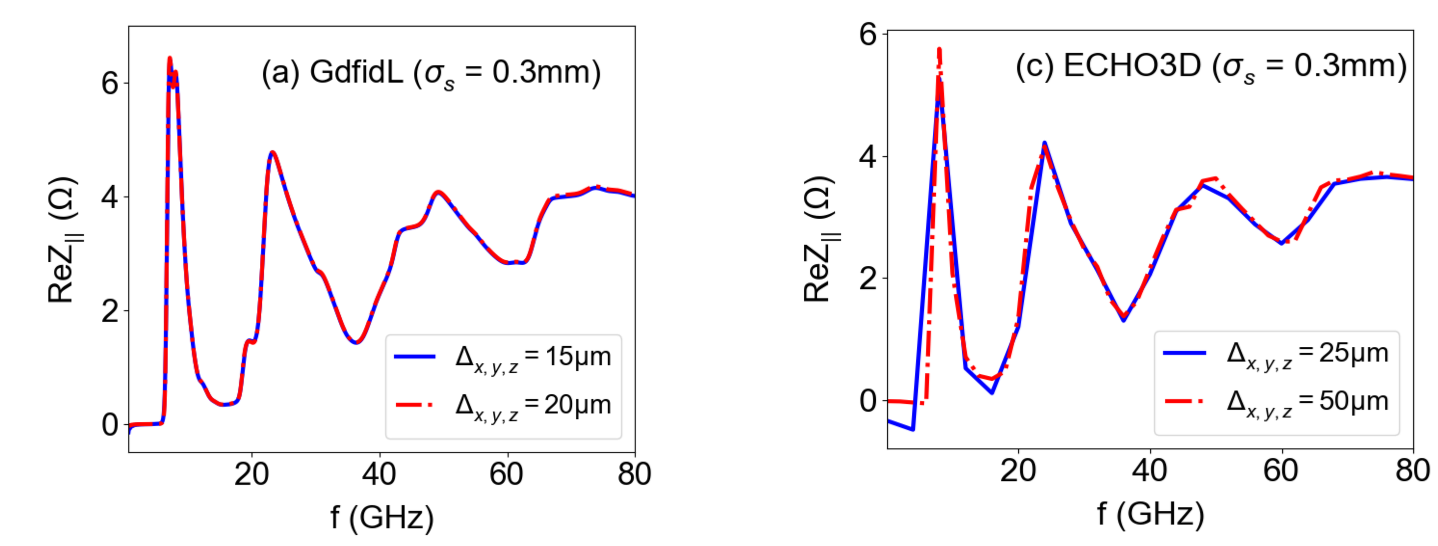


Fig.2: Convergence studies of real part of longitudinal impedance with GdfidL and ECHO3D for a point bunch 0.3mm of the NSLS-II flange absorber.

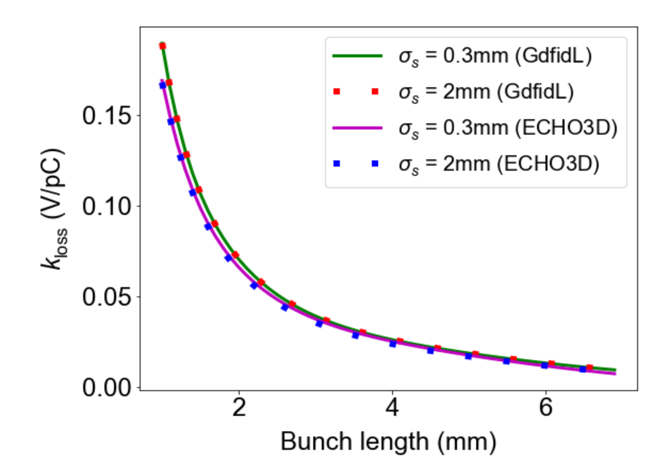


Fig. 3: Comparison of loss factor as a function of bunch length for the NSLS-II flange absorber.

- A good agreement between both codes
- GdfidL requires fine mesh compared to the ECHO3D.
- ECHO3D is memory consuming and troublesome for long-length wake post-processing

NSLS-II RF bellows:

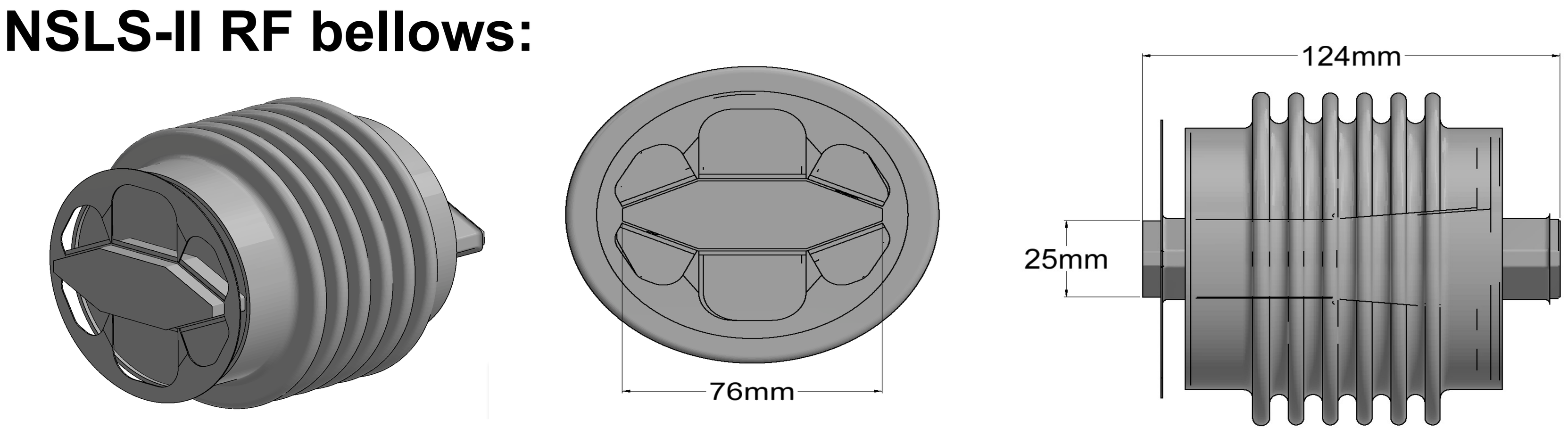


Fig.4: Schematics of the NSLS-II RF bellows.

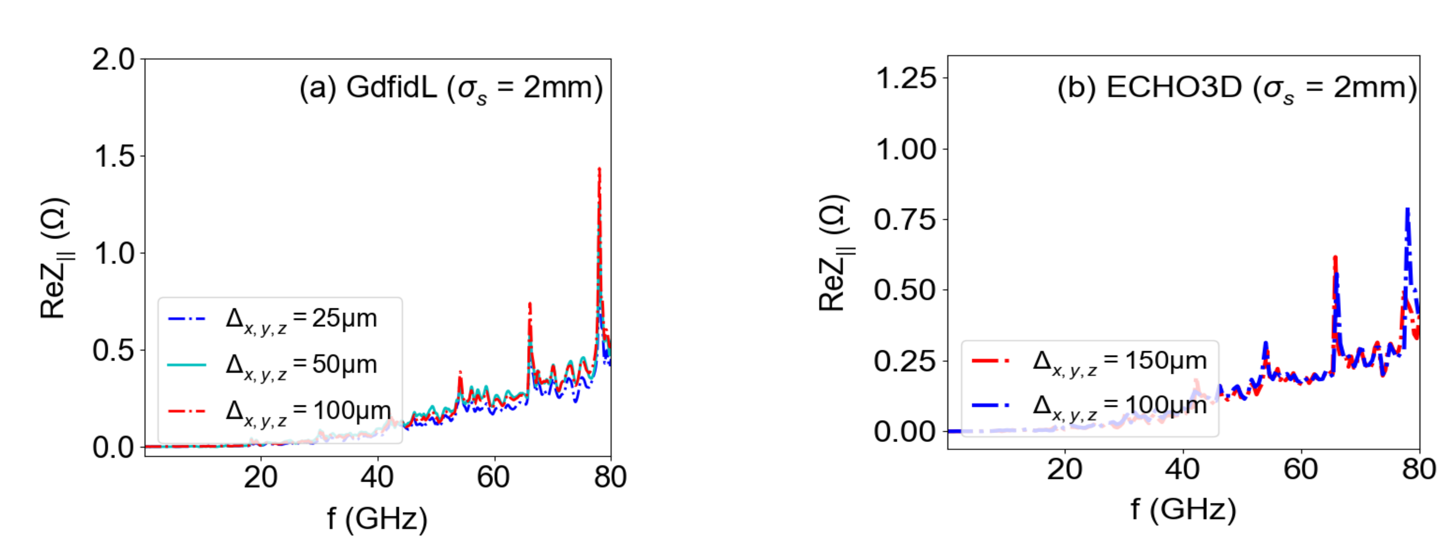


Fig. 5: Convergence studies of real part of longitudinal impedance with GdfidL and ECHO3D for a point bunch 2 mm of the NSLS-II RF bellows..

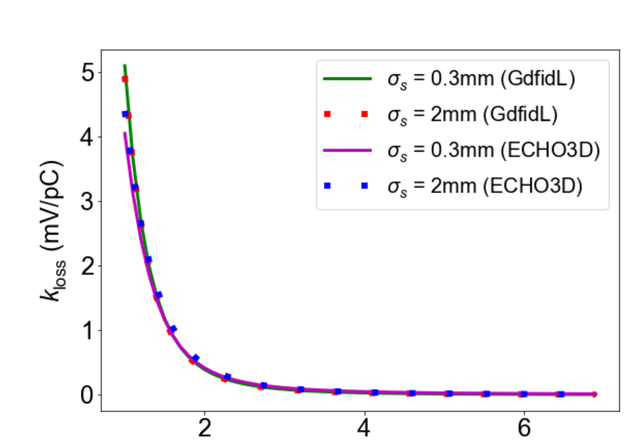


Fig. 6: Comparison of loss factor as a function of bunch length for the NSLS-II RF bellows.

- For 124 mm bellows:
  GdfidL → 48 hrs on 8-nodes
  ECHO3D → 8 hrs on a single node

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