Calculation of Loss Factor & Impedance of KEKB IR

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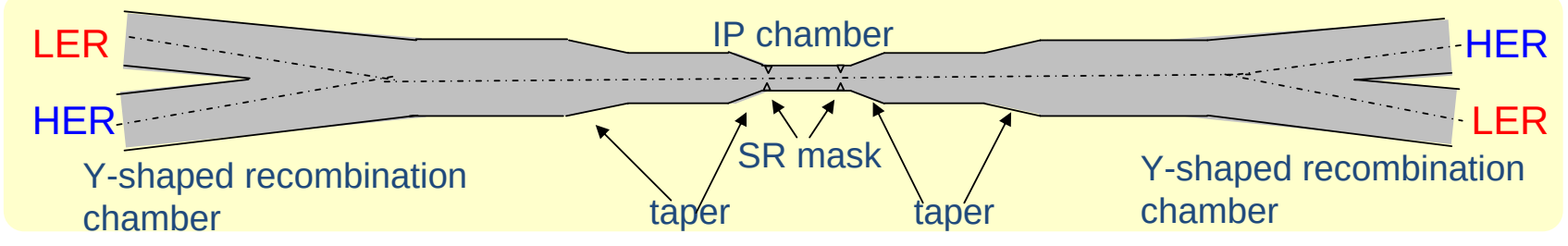
Introduction

- IR beam duct has big impedance.
  - When beam passes through IR beam duct, the beam interacts with its surroundings.
    - Heating problems
      Beam deposits its energy in the form of the higher order mode (HOM).
      HOM propagates along the beam duct, and heats up adjacent components.
      How much is the power deposition? ⇦ Must be estimated from Loss Factor.
    - Beam instabilities
      Beam is disturbed by HOM and beam instabilities occur.
      If growth rate is larger than damping rate, beam can not be stored.
      How much is the growth rate? ⇦ Must be estimated from Impedance.
  - Recalculations of loss factor and impedance of KEKB IR have just begun recently, because estimation of them in design stage was insufficient due to poor computational capability.



Method for Calculation

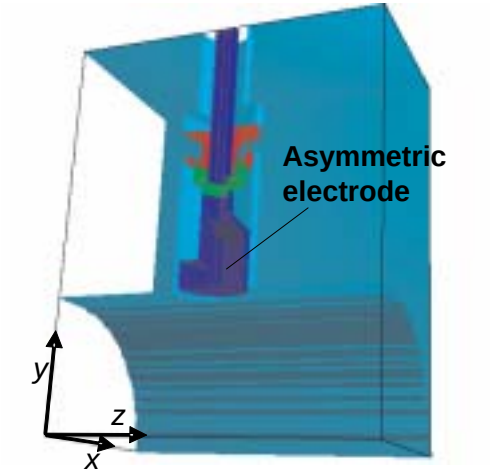
- Simulation codes for computation of electromagnetic fields
  - MAFIA
    - 2D (axisymmetric) and 3D simulations are available.
    - Maximum memory size is 8 Gb (not enough).

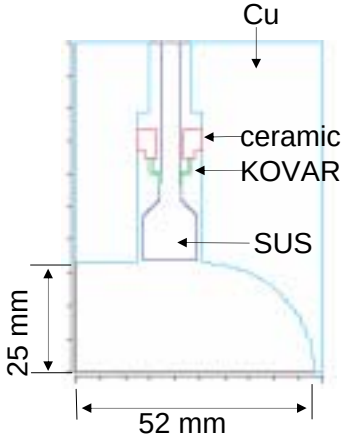
      If 2D simulation is available, we can cut down on computation time and memory size drastically.
  - GdfidL
    - Only 3D simulation is available.
    - Parallel computation is available.
    - Maximum memory size is 16 Gb and more.

      For calculation of big or non-axisymmetrical components, we have to use GdfidL
- Calculation procedure
  - Simulation codes calculate electromagnetic field generated by beam and its surroundings (wake field).
  - Loss factor and impedance are obtained from wake field and charge distribution of bunch.

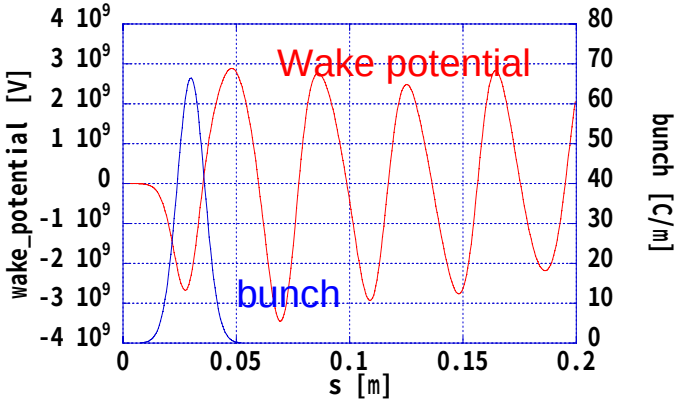
Method for Calculation

- For example (in case of BPM)
  - Model



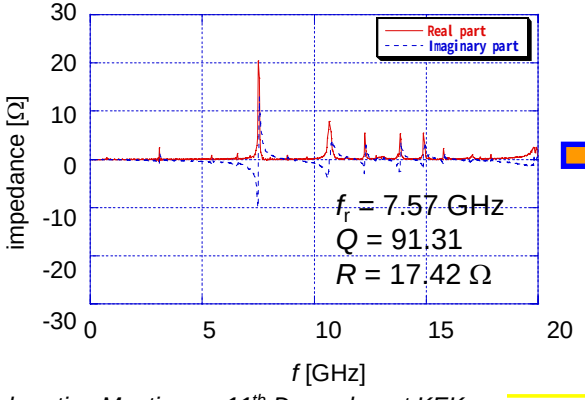


  - Wake field (wake potential)



  - Loss factor and Impedance

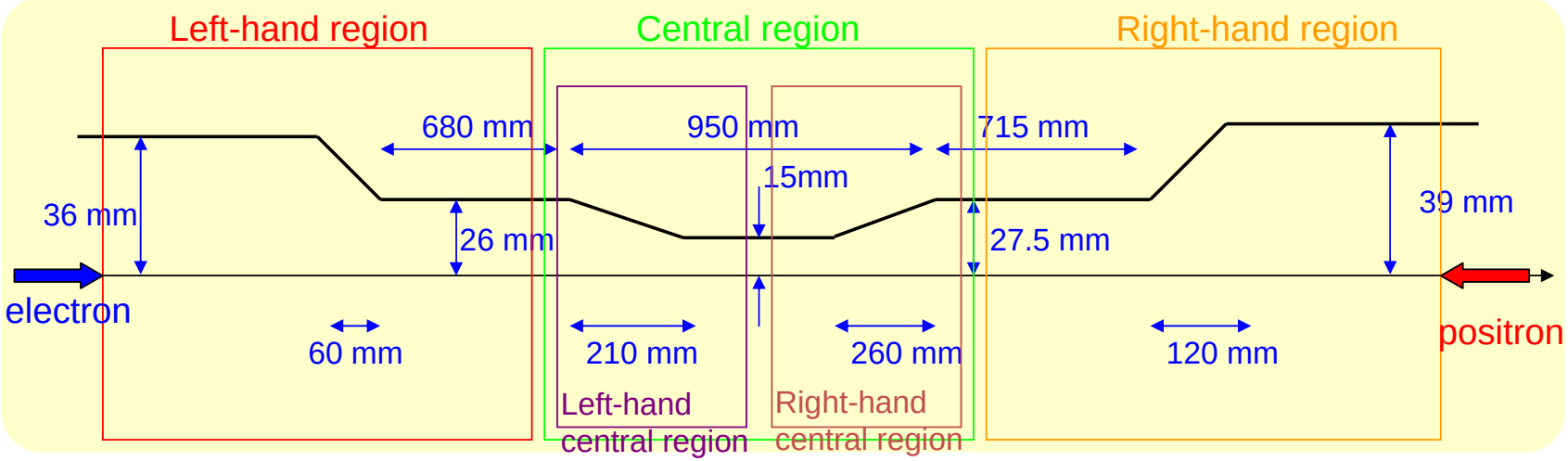
Loss factor = 1.3×10^{-3} V/pC → Estimation of power deposition



→ Estimation of growth rate of instabilities and I_{max}

Calculation Model

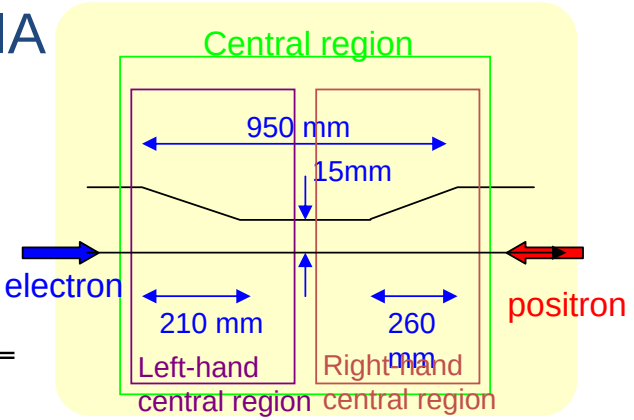
- Calculation of KEKB IR
  - Modeling
    - For simplification we made axisymmetrical model without ‘IP mask’ and ‘Y-shaped recombination chambers’ at first.
      - ⇨ Both MAFIA 2D solver and GdfidL are available.
    - IR duct is divided into several regions.
      - ⇨ Cutting down on memory size



Loss Factor 1

- Comparison between GdfidL and MAFIA
  - Central region
    - Electron : Beam (σ_z=4 mm) runs left to right

	Loss factor [V/pC]	
	MAFIA(2D)	GdfidL
Left-hand central region	-0.652	-0.651
Right-hand central region	0.981	0.920
total	0.329	0.269
Central region	0.311	0.263



- Positron : Beam (σ_z=4 mm) runs right to left

	Loss factor [V/pC]	
	MAFIA(2D)	GdfidL
Left-hand central region	0.839	0.841
Right-hand central region	-0.732	-0.734
total	0.108	0.108
Central region	0.274	0.0670

⇐ MAFIA ≠ GdfidL
Unreliable?

Loss Factor 2

- Comparison between GdfidL and MAFIA
  - Whole length
    - Electron : Beam (σ_z=4 mm) runs left to right

	Loss factor [V/pC] MAFIA(2D)	GdfidL
Left-hand region	-0.441	-0.350
Right-hand region	0.592	0.516
total	0.151	0.166
Total + Central region (whole length)	0.481	0.435

    - Positron : Beam (σ_z=4 mm) runs right to left

	Loss factor [V/pC] MAFIA(2D)	GdfidL
Left-hand central region	0.618	0.503
Right-hand central region	-0.501	-0.391
total	0.117	0.112
Total + Central region (whole length)	0.225	0.219

Loss Factor 3

- Estimation of power deposition
  - Power deposition is calculated from loss factor k [V/C], beam current I_0 [A] and bunch spacing T_b [s].

$$P\ [\mathrm{W}] = kI_0^2T_b$$

  - Estimation from design parameters

		Electron (HER),	Positron (LER)
Beam current I_0	[A]	1.1	2.6
Bunch spacing T_b	[ns]	2	
Bunch length σ_z	[mm]	4	
Loss factor k	[V/pC]	0.45	0.22
Power deposition [kW]		**1.1**	**3.0**

  - Estimation from present parameters

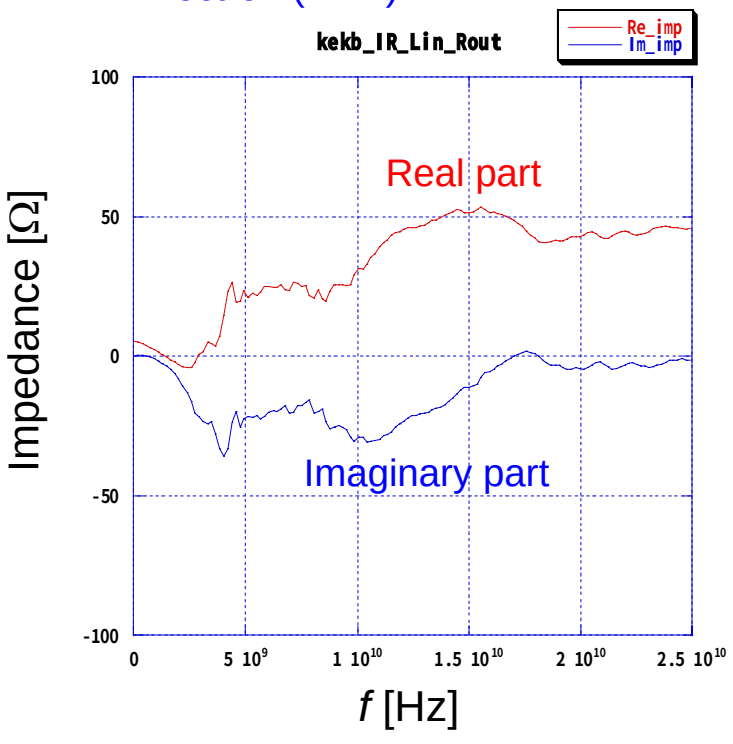
		Electron (HER),	Positron (LER)
Beam current I_0	[A]	1.0	1.6
Bunch spacing T_b	[ns]	6	
Bunch length σ_z	[mm]	6	
Loss factor k	[V/pC]	0.30	0.15
Power deposition [kW]		**2.0**	**2.3**

Deposit energy propagates along the beam duct.

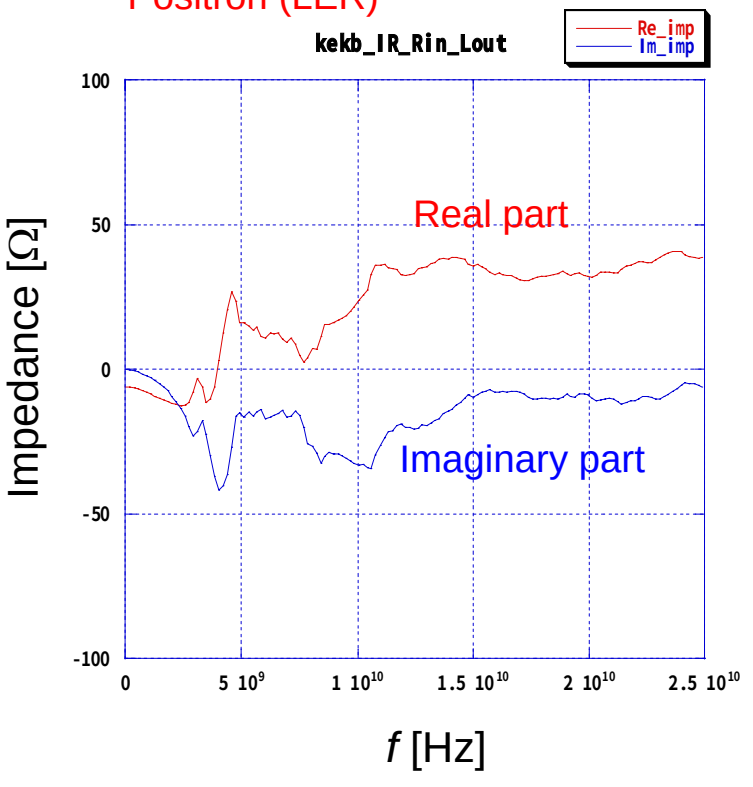
Impedance

- Results of GdfidL
  - Results of GdfidL seem to be reliable. (Results of MAFIA were not good.)
  - Estimation of beam instability is not yet considering.

Electron (HER)



Positron (LER)



Summary

- Recalculation of KEKB IR Loss factor & Impedance have just begun.
  - Only loss factor & Impedance of simplified IR duct have been done.
    - MAFIA & GdfidL seem to be useful simulation codes.
  - There are still many things to do.
    - Calculation of ‘IP Mask’ and ‘Y-shaped recombination chambers’
    - Beam instability estimation
    - Comparison between simulation and measurement
    - And so on…
- In design stage of SuperKEKB IR, calculation of loss factor and impedance is necessary.
  - How about HOM power deposition?
  - Can we stored high current beam?