ISBN: 978-3-95450-214-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2021-MOPAB127

CONSTRUCTION OF AN IMPEDANCE MODEL FOR DIAMOND-II

R.T. Fielder†, T. Olsson, Diamond Light Source, Oxfordshire, UK

Abstract

Impedance models for accelerators have traditionally been presented in a static form, usually as tables or spreadsheets which must be read manually. As part of the Diamond-II upgrade work, we have developed an impedance model using a lattice structure. This allows more direct integration with simulation codes while keeping important information easily human readable. We present here a description of this implementation method, along with an overview of the Diamond-II impedance model derived from the latest engineering design.

INTRODUCTION

Diamond-II is a planned upgrade to the Diamond synchrotron light source. The aim of pushing to lower beam emittance to provide higher brightness requires stronger magnets with smaller pole-tip spacing and so smaller vacuum vessels. The most recent progress on the lattice design is presented in [1]. Impedance is therefore a major concern as a restriction on bunch current thresholds and beam stability.

We have developed an impedance database using a lattice structure to allow results from impedance calculations to be easily integrated into particle tracking and other simulation codes, while remaining in a human-readable format. This also allows us to easily update the database as the design of the machine progresses.

IMPEDANCE MODEL STRUCTURE

Components in the vacuum chamber do not necessarily overlap precisely with the magnets. This presents a problem in integrating impedance and apertures with the magnetic lattices used in many tracking codes, such as Accelerator Toolbox [2] and Elegant [3, 4]. We have therefore developed an impedance lattice using an Accelerator Toolbox-like structure which allows a ring to be created from a series of impedance elements.

Each impedance element contains details of the component including length, material, apertures, and so on. It also contains links to files containing the full wake potentials and impedances calculated using CST Studio Suite [5]. These can be read in to codes such as Elegant and mbtrack [6].

Impedance simulations were carried out using CST Studio Suite. These simulations have so far used mainly a 3 mm bunch length, which allows relatively quick simulations while designs are being iterated. Final impedance calculations will use a 1 mm bunch length. All simulations are carried out using perfect conductor (PEC), with the resistive wall impedance calculated separately, allowing the effects of different contributions to be assessed independently.

DIAMOND-II GIRDER OVERVIEW

Diamond-II has a six-fold symmetry. Each superperiod consists of eight arcs, each with a single girder, separated by straights of varying lengths. There are four types of girder, defined by which straights are at their ends – long-mid (LM), mid-standard (MS), standard-mid (SM), and mid-long (ML). The full layout of a superperiod is thus LM, MS, SM, MS, SM, MS, SM, ML.

So far the bulk of design work has focussed on the LM girder. It is assumed that the other girders will share as much in common with this design as possible. The majority of the vessel will be a cooled cylindrical copper vessel with NEG coating (see Fig. 1). The upstream dipole uses an aluminium vessel with an antechamber structure, that allows photons from the upstream insertion device (ID) to be extracted. Other significant components include the gate valves adjacent to the straights, BPMs, flanges, and pumping ports.

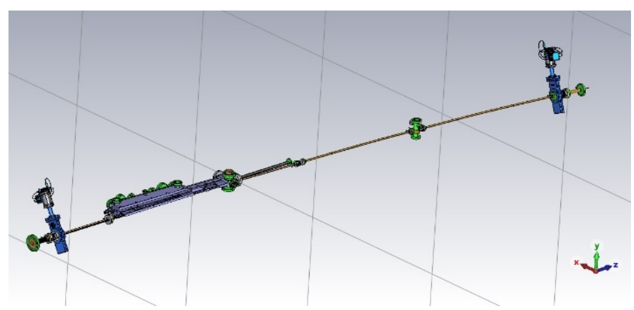

Figure 1: 3D overview of the Diamond-II LM girder.

COMPONENT DETAILS

Resistive Wall

Table 1 shows a summary of the materials used for the resistive wall component of the impedance. This does not include details of individual straights, since each ID will need individually designed transitions. Note that the full details of the NEG coating are yet to be finalised, but see [7] for further details.

Table 1: Materials and Proportion of Vacuum Vessel

Material	Conductivity (S/m)	Length (m)	Part of Ring (%)
Copper (no NEG)	5.96e7	415.76	74.2
Aluminium	3.77e7	96.00	17.1
Stainless steel	1.35e6	48.80	8.7

† richard.fielder@diamond.ac.uk

ISBN: 978-3-95450-214-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2021-MOPAB127

BPMs

The BPM assemblies contain the BPM block, bellows, flanges, and upstream and downstream tapers (see Fig. 2). The assembly tapers out to larger radius to protect the BPM buttons from synchrotron radiation. The impedance of the BPM block itself is significantly improved over those in the existing Diamond ring, however, the tapers reduce the performance to about the same level. One BPM has an additional vacuum pump incorporated into the assembly.

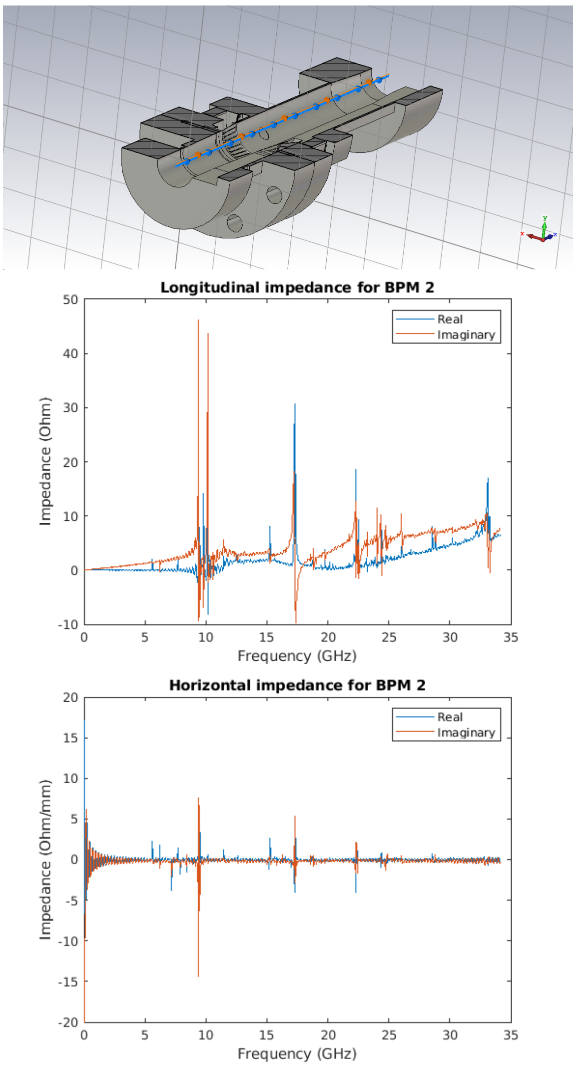

Figure 2: 3D model (top), and longitudinal (middle) and horizontal (bottom) impedance for BPM assembly.

Dipole Vessel

The vessel for the first dipole on the girder uses an antechamber structure that allows the photons beam from the upstream ID to be extracted (see Fig. 3). Due to the size and complicated shape, this part cannot be made from copper and is instead aluminium. Several internal supports are still needed to maintain the structure. Since this part will not be NEG coated, there are several vacuum pumps on the antechamber. There are also two finger absorbers and a crotch absorber for synchrotron radiation; the details remain under design to ensure the absorbers are sufficient for the incoming photon power. There is also a BPM at the downstream crotch which is included in this component rather than being considered separately.

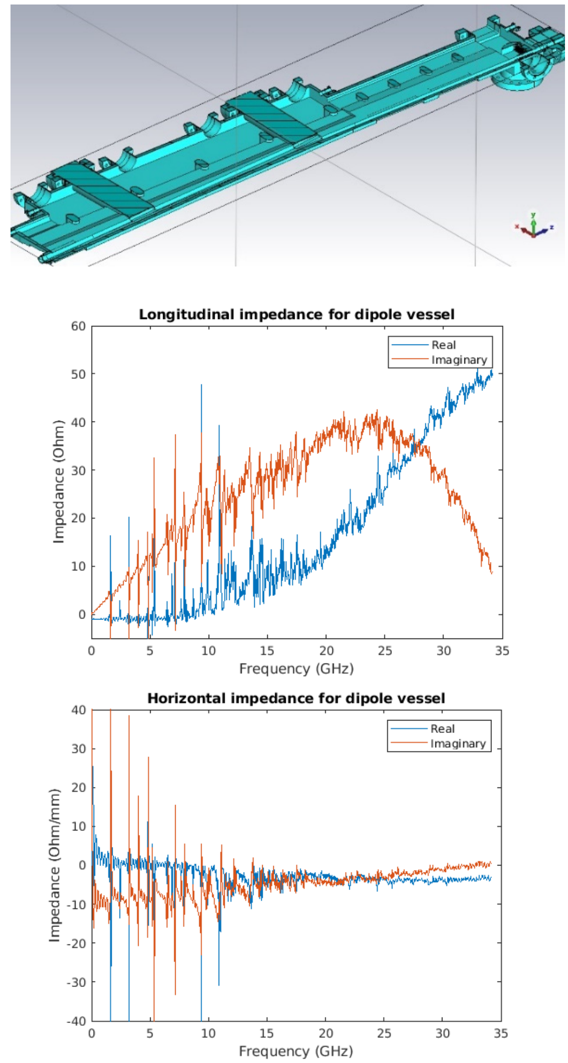

Figure 3: 3D model (top), and longitudinal (middle) and horizontal (bottom) impedance for aluminium dipole vessel.

Stripline Kickers

A new design for stripline kickers has been produced. This has tapered ends and curved plates to match the incoming vessel's profile and reduce step transitions as much as possible (see Fig. 4). This has greatly improved impedance characteristics over the existing Diamond striplines. It is planned to use the same design for the transverse multibunch feedback in both planes. A similar design may also be used in the booster, and is also being investigated for injection.

RF Cavities

Diamond-II will use eight HOM-damped normal conducting cavities for RF power instead of the superconducting cavities in the existing ring. Due to the high frequency

ISBN: 978-3-95450-214-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2021-MOPAB127

resolution required to fully characterise the main modes, simulation work on these is ongoing.

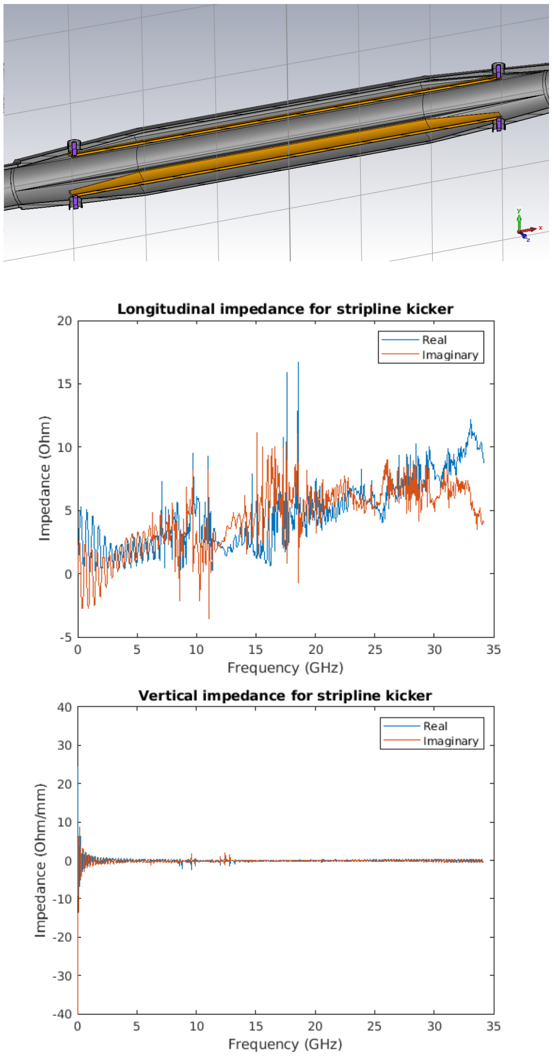

Figure 4: 3D model (top), longitudinal (middle) and vertical (bottom) impedance for a stripline kicker.

There will also be a third order harmonic cavity for bunch lengthening, but the design for this has not been chosen yet. Both active and passive options, and normal or superconducting, are still under review.

Flanges

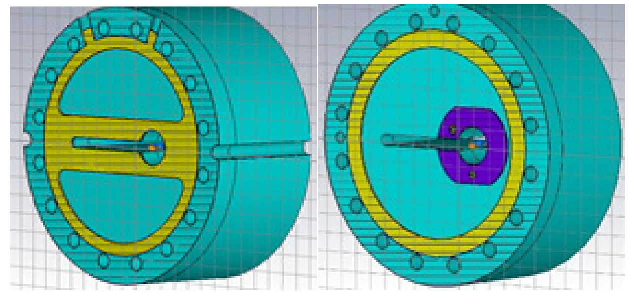

Figure 5: Flange design with copper gasket (top) and copper (yellow) and aluminium (purple) gasket (bottom).

Several flange types have been assessed, two of which are shown in Fig. 5. The preferred design uses a copper gasket, or a combination of copper and aluminium, pressed between the flange plates, which produces a true zero-gap for RF continuity. The effects of gasket tolerances have also been assessed.

Summary

An overview of the longitudinal loss factors and transverse kick factors is shown in Table 2. The large dipole vessel is clearly the most significant contribution to the transverse impedance in both planes, and work is ongoing to improve this. No single component dominates the longitudinal, although the resistive wall impedance is significant as shown in [7].

CONCLUSION

An impedance database has been created for Diamond-II based on the engineering design work done so far. Work is ongoing to complete the design, and to improve existing components where possible. A lattice-like structure has been created to hold this database and allow easy integration with common tracking and simulation codes.

Table 2: Breakdown of Contributions to the Storage Ring Impedance

Component	Number in ring	Total Loss factor (V/pC)	Total Hor. Kick Factor (V/pC/mm)	Total Vert. Kick Factor (V/pC/mm)
BPM1	48	3.8688	-1.4304	-0.6096
BPM2	12	0.2520	-0.0552	-0.0600
BPM4	48	1.8384	-0.5232	-0.6000
BPM5	48	2.2416	-0.4670	-0.5280
BPM6	48	1.9872	-0.5664	-0.5712
Dipole vessel	48	5.6160	-9.3600	-1.4448
Round flange	528	0.0158	0.0634	-0.1214
Valve	96	4.0992	-0.1152	-0.5664
Cavity	8	9.4880	0.0091	-0.0006
Stripline	2	0.1642	-0.0113	-0.0252

ISBN: 978-3-95450-214-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2021-MOPAB127

REFERENCES

[1] H. Ghasem, I. P. S. Martin, and B. Singh, "Progress with the Diamond-II Storage Ring Lattice", presented at the 12th Int. Particle Accelerator Conf. (IPAC'21), Campinas, Brazil, May 2021, paper THPAB090, this conference.

[2] "Accelerator Toolbox", ATCOLLAB, version 2.0, `https://atcollab.github.io/at/`.

[3] M. Borland, "elegant: A Flexible SDDS-Compliant Code for Accelerator Simulation", Advanced Photon Source LS-287, September 2000.

[4] Y. Wang and M. Borland, "Pelegant: A Parallel Accelerator Simulation Code for Electron Generation and Tracking", in *Proc of the 12th Advanced Accelerator Concepts Workshop*, *AIP Conf. Proc.* vol. 877, pp. 241, 2006. doi:10.1063/1.2409141

[5] CST Studio Suite, `https://www.3ds.com/products-services/simulia/products/cst-studio-suite/`.

[6] G. Skripka, R. Nagaoka, M. Klein, F. Cullinan, and P. F. Tavares, "Simultaneous computation of intrabunch and interbunch collective beam motions in storage rings", *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, vol. 806, pp. 221–230, Jan. 2016. doi:10.1016/j.nima.2015.10.029

[7] T. Olsson and R. T. Fielder, "Single-Bunch Thresholds for the Diamond-II Storage Ring", presented at the 12th Int. Particle Accelerator Conf. (IPAC'21), Campinas, Brazil, May 2021, paper MOPAB072, this conference.