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Transverse broad-band impedance studies of the new in-vacuum cryogenic undulator at BESSY II SR

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MORE INFORMATIONS

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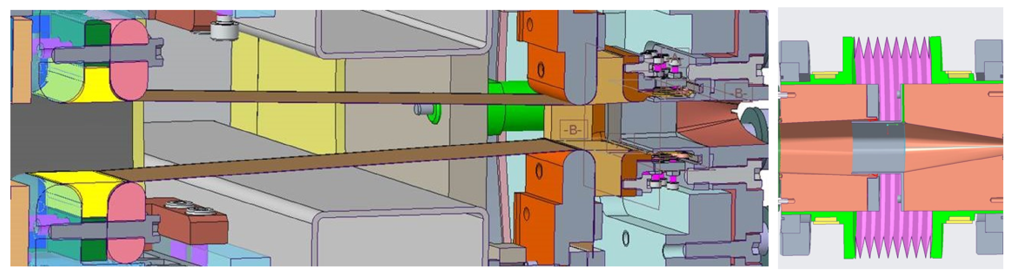
ABSTRACT: A beam based measurement using orbit bump method has been applied to estimate the vertical impedance of CPMU17. For CPMU17 the first results of broad-band impedance studies are presented, including the measurement results form orbit bum and from tune shift measurement and simulation.

MOTIVATION

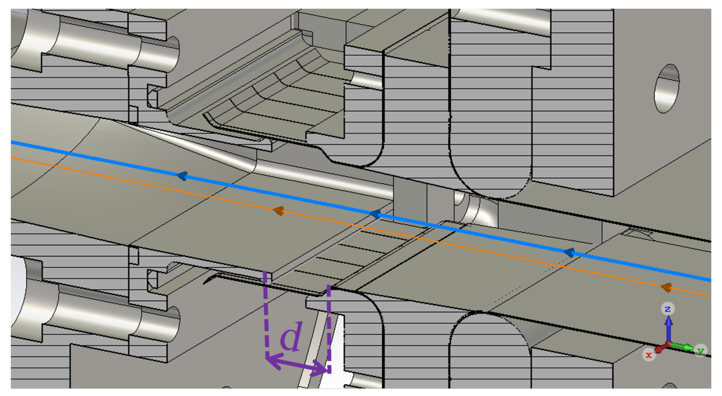
The first radiation from the cryogenic permanent magnet undulator (CPMU17) has been observed in December 2018 at the BESSY II storage ring at HZB, and since then this device has served as a light source for beamline commissioning. It is the first in-vacuum undulator installed at the BESSY II, and a new in-vacuum APPLE undulator (IVUE32) is planned to be installed in near future. Thus, a detailed study of the interactions between such an in-vacuum device and the electron beam is required.

CPMU17 MODEL AND SIMULATION

CPMU17 Taper taper foil, taper section and bellow at downstream

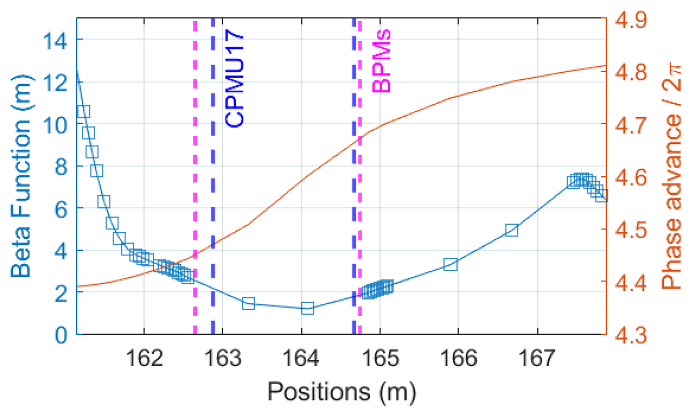


Taper section, closer view



CST simulation for taper section and RF schileding foils: $k \approx 2 \times 10^{14}$ V/C/m .

Beta function and phase at CPMU17 straight, within the bump



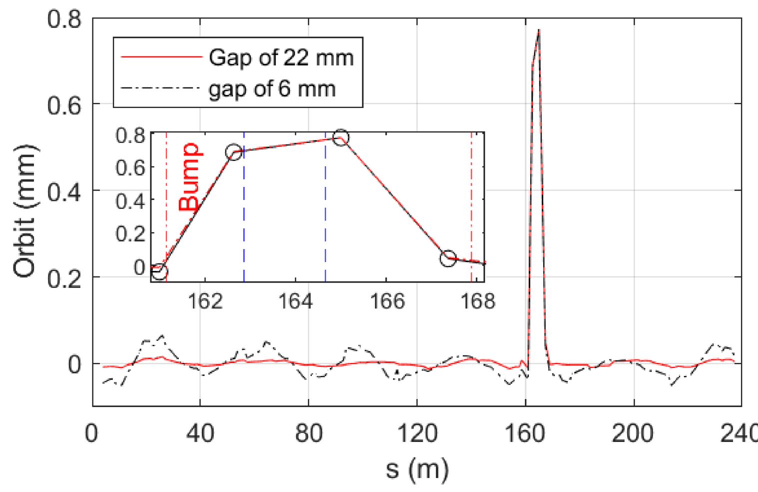
THEORY AND METHODS

Orbit Bump method (OBM)

Transverse kick factor defined by [1]: $k_\perp = \frac{1}{2\pi}\int_{-\infty}^{\infty} Z_\perp(\omega)h(\omega)\mathrm{d}\omega$, change in beam vertical momentum: $\Delta y' = eqk_\perp y_0/E$. closed orbit distortion (COD) due this kick is [1]:

$$\Delta y(s) = \frac{\Delta q}{E/e}k_\perp y_0 \frac{\sqrt{\beta(s)\beta(s_0)}}{2sin\pi Q_y}cos(|\mu(s)-\mu(s_0)|-\pi Q_y). \quad (1)$$

4 states combination of *high-*, *low-current* and *with-*, *no-bump*: $\Delta y(s) = (\Delta y_{wbh} - \Delta y_{nbh}) - (\Delta y_{wbl} - \Delta y_{nbl})$, COD equal to $\Delta y(s)$ directly proportional to $k_\perp$.



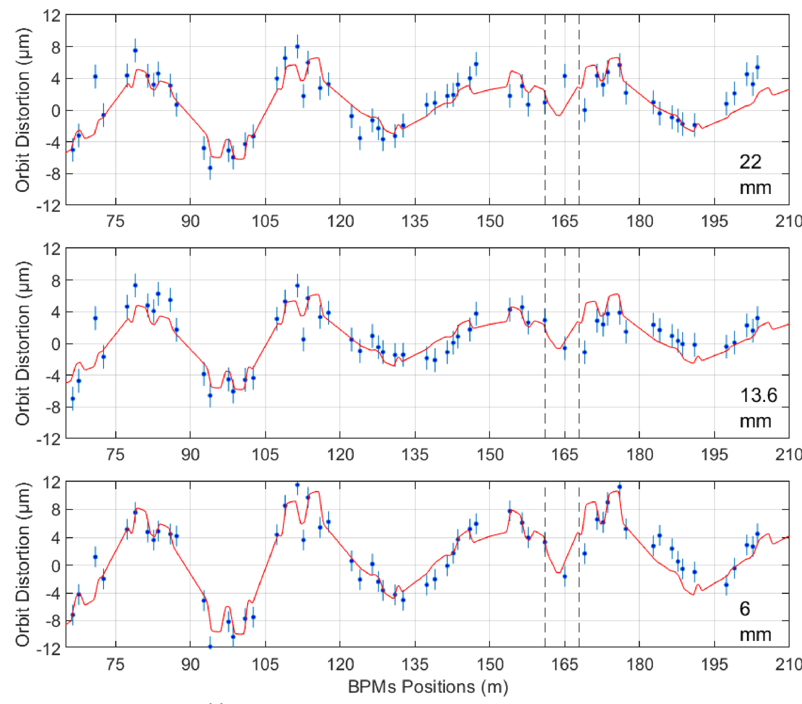
Tune shift with single bunch current variation

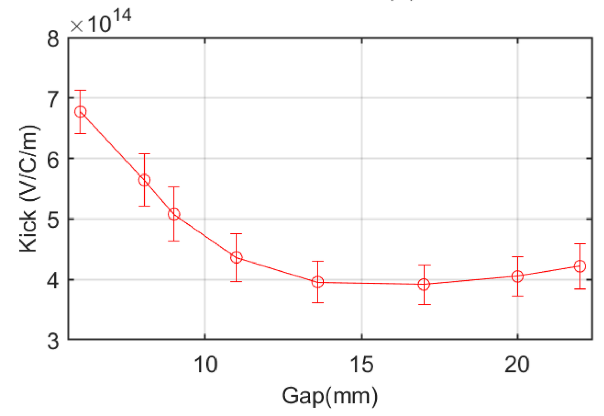
The slope of the variation of the vertical betatron tune was measured vs. single bunch current change. This slope is an indication of the vertical kick factor:

$$\frac{dQ_{yF}}{dI_b} = -\frac{<\beta> k_\perp}{2\pi\nu_{rev}(E/e)}, \quad (2)$$

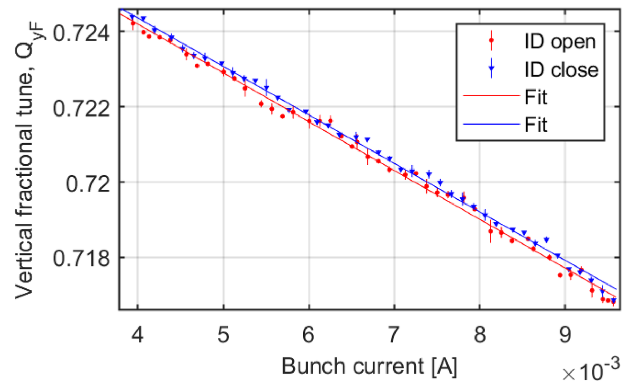
RESULTS

Closed orbit distortion $\Delta y(s)$ at gap of 6 mm, 13.6 mm and 22 mm. Fitting with Eq. (1) yields Kick factors: $[(6.8\pm0.4), (4.0\pm0.3), \text{and } (4.2\pm0.4)][\times 10^{14}$ V/C/m], respectively.





Tune shift vs. bunch current:



Slope difference between IDopen and ID cloed case: $(-1.2864\pm0.076)A^{-1}-(-1.2954\pm0.011)A^{-1} = (9.1\pm13.6)\times10^{-3}A^{-1}$. Substituting in Eq.(2): $\Delta k_y = (1.5\pm2.2)\times 10^{14}$V/C/m. From OBM we have: $\Delta k_y = (2.6\pm0.5)\times10^{14}$V/C/m. Accruracy of 20 ± 4Hz for vertical betatron frequency is needed for this method.

CONCLUSION

- The major impedance contributors of the first cryogenic permanent undulator at BESSY II have been identified, and the impact of the taper section, magnets-shielding and tapered foils on the impedance are separately approximated using CST simulations.
- The vertical kick factors have been experimentally evaluated using orbit-bump and tune-shift techniques.
- The results of the two measurement methods and the simulation agree to a good extent.
- Further studies with more accurate measurements, data analyses, simulations and theoretical models are being carried out, to determine and compare the contributions of all ID parts in to the impedance.
- A modification of the vacuum chamber is under development to investigate possible resonances by installing RF antennas in ID vacuum chamber.
- Studies of coupled bunch instabilities, in particular growth-damp measurements are planned.
- The impedance evaluation will be also conducted with few-bunch and multi-bunch fill patterns.

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