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A New Method of Undulator Phase Tuning with Mechanical Shimming*

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Introduction

- We developed a new method for tuning the undulator phase errors by shimming the undulator gap profile mechanically.
- First, the phase errors of a device are calculated based on the initial field measurement; then the desired field strength modulation along the device length is derived from the phase errors; and finally, the gap profile is mechanically shimmed to produce the desire field strength modulation.
- The method has been successfully applied to the tuning of many new and reused APS Upgrade (APS-U) hybrid permanent magnet undulators. The method is especially effective for tuning the legacy undulators with large phase errors.
- For instance, an old 33-mm-period undulator with a 23-degree initial RMS phase error largely due to radiation damage has been tuned to better than 3 degrees.

Equations

For a Hybrid Permanent Magnet Undulator(HPMU), field change ΔB_i due to gap deformation Δg_i, i is the pole index.

$$\Delta B_i = -\pi \frac{\Delta g_i}{\lambda_u} \bar{B}$$

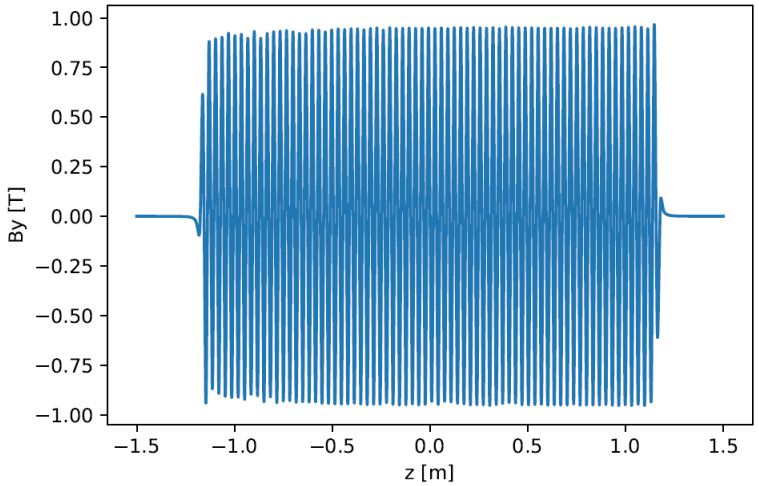
Ideally, phase advance between two neighboring magnets should be π. However, due to the above gap deformation-based field changes, the phase advance is no longer π, the phase error is:

$$\delta\phi_i = -\pi^2 \frac{2\bar{K}^2}{2+\bar{K}^2} \frac{\Delta g_i}{\lambda_u} \qquad (1)$$

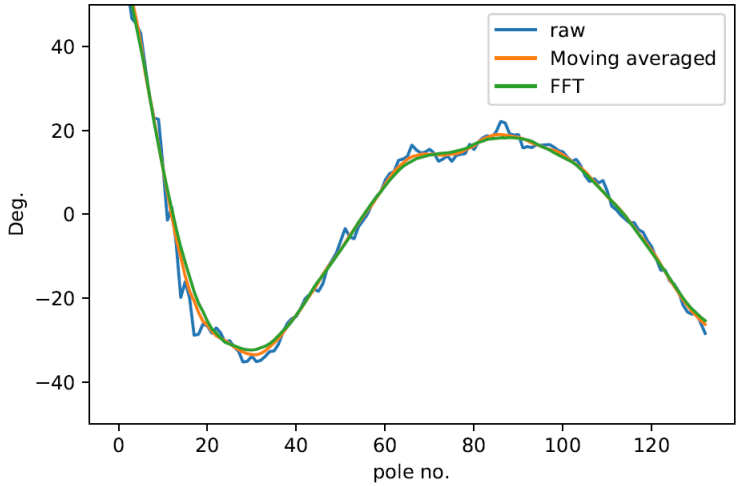
If the phase error $\delta\phi_i$ is obtained from magnetic field measurement, one can get a gap profile Δg_i that best compensates the phase error by using the above equation.

Implementation Example

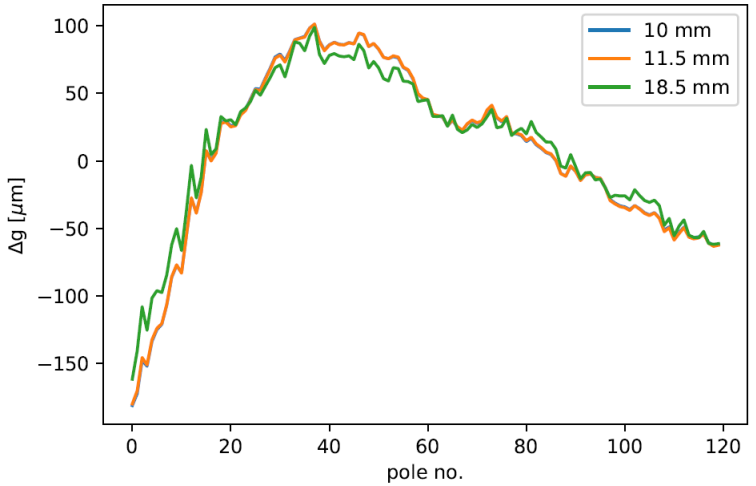
- A legacy HPMU U33#19S is used as an example.
- Period length: 33 mm, poles: 146, gap range: 10~30 mm.



- Field at the z- end is weakened due to demagnetization effect.(it has a history of 25 years).
- The initial RMS phase error at the 10-mm gap is 23°.



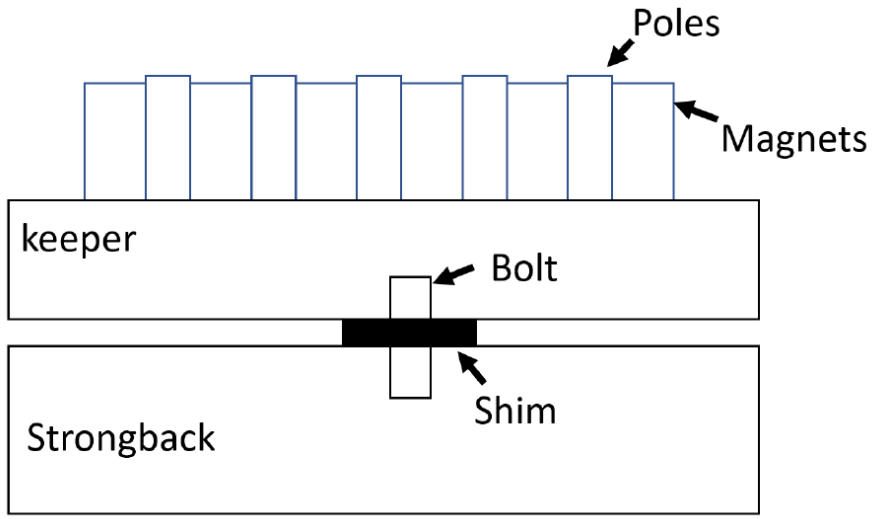
The initial phase error distribution as a function of poles, and its trendlines.

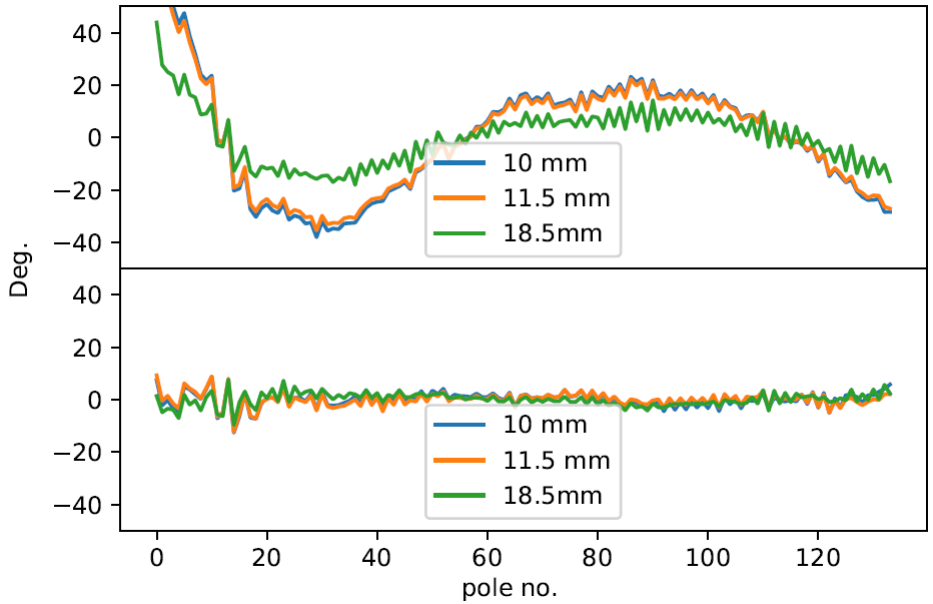


- Phase error trendlines (from moving average method) at different gaps were translated into the required gap deformation profiles using Eq. (1).
- Required gap deformation profile at the 10-mm gap is used for gap shimming.

Implementation Example

- Gap shimming is performed by changing the thickness of the shim between the keeper and the strongback.
- The resolution of the thickness of shims is 12 μm.

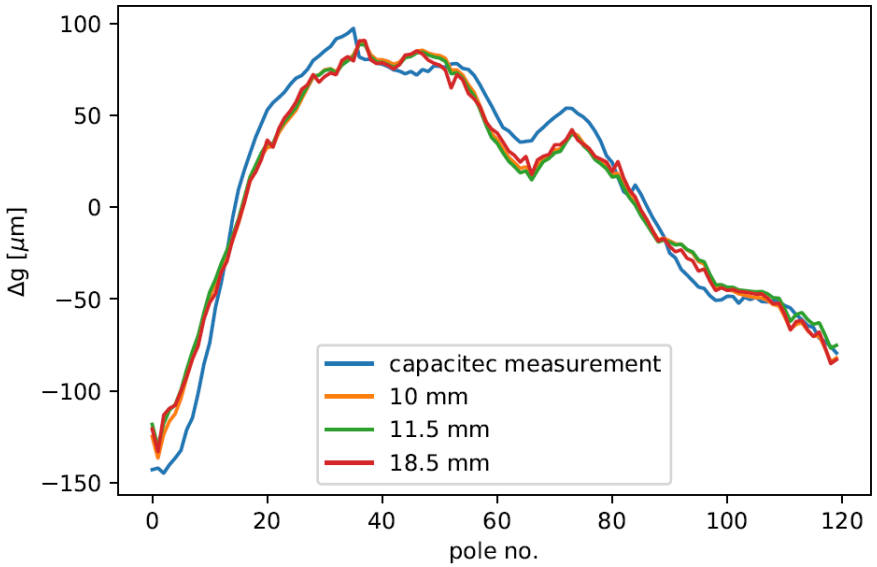




- RMS phase error at the 10-mm gap was reduced to 2.94° after two rounds of gap shimming.
- RMS phase errors at other gaps are all better than 3° and meet the specification of APS-U undulators.

Consistency

- Capacitec measurements that were taken before and after gap shimming determines the gap deformation.
- Gap deformation profiles are also calculated by using Eq. (1) from phase errors at different gaps before and after shimming.
- Comparison of these gap deformation profiles shows that our method of calculating gap deformation from phase is consistent with the Capacitec measurement.



Conclusion

- In this report, we present a new and efficient method for phase error correction by mechanically shimming the gap with the guidance of phase error.
- This approach has been successfully applied to all nine re-tuned legacy HPMU devices and one new HPMU device constructed for the APS-U project.
- The accurate calculation of the desired gap deformation reduces the number of iterations of gap shimming and reduces the cost of time and effort. Hence, it is useful for projects with a large number of HPMU devices, especially for projects that need to tune HPMU devices of poor quality.
- This method can be used in the phase error correction of the superconducting undulators, too.