Aberration correction study for high-resolution optics of BigRIPS using sextupole magnets

T. Nishi,[*1] D. S. Ahn,[*1] N. Fukuda,[*1] N. Fukunishi,[*1] H. Geissel,[*1,*2] N. Inabe,[*1] K. Itahashi,[*1] K. Kusaka,[*1] S. Y. Matsumoto,[*1,*3] Y. Shimizu,[*1] T. Sumikama,[*1] H. Suzuki,[*1] M. Takaki,[*4] H. Takeda,[*1] Y. K. Tanaka,[*1,*2] T. Uesaka,[*1] Y. Yanagisawa,[*1] and K. Yoshida[*1]

We performed a test experiment in May 2018 to develop new optics of BigRIPS with higher order aberrations diminished by sextupole magnets. The optics is designed for spectroscopy of deeply bound pionic atoms[1)] and search for double Gamow-Teller giant resonance.[2)] Until now, we have achieved double the resolving power with the new optics compared to a standard design; however higher order aberrations remain. For example, the correlation between the horizontal position and the angle at F5 strongly depends on momentum, which is referred to as $(x|a\delta)$. In other words, the focal plane at F5 is inclined at 87° (almost parallel to the beam axis). This causes position-dependent deterioration of the resolution coupled with multiple scattering. To improve this condition, we developed a new optics using sextupoles.

Taking advantage of the mirror-symmetrical configuration of the magnets in BigRIPS, we designed a new optical setting as shown in Fig. 1. Trajectories in several corresponding sections, namely between F0-F1 and F1-F2, and between F3-F5 and F5-F7, are designed to be symmetric at the first order. The field strengths of the sextupoles are also constrained to have (anti) symmetry in the same sections based on the sextupole coupling coefficients.[3)] Through these constraints, many aberrations will be canceled out, and others are expected to have simple responses to the field strengths of the sextupoles.

In the test experiment, we systematically varied the field strengths of the sextupoles and measured the aberrations. We utilized fragments of ^{9}C produced by a primary ^{18}O beam of 230 MeV/nucleon and a 30 mm thick Be target. The ^{9}C distributions in terms of angle and momentum are large enough to have a nearly flat distribution in the acceptance of BigRIPS. We detected ^{9}C by PPACs at F3, F5, and F7 and a plastic scintillator at F7. Aberration coefficients such as $(x|a^2)$ or $(x|a\delta)$ were evaluated at F3 and F5. During the measurement, we applied very narrow momentum gates of 0.1%, which were set by time of flights between F0 and F7 using the RF and F7 scintillator signals.

As a result, we found clear dependence of aberration coefficients on the sextupole settings as expected; further, we optimized the settings to suppress the aberrations. Figure 2 shows correlation between position and angle in the horizontal direction at F5, where our main detectors will be installed, with the sextupoles all off (left) and all on after optimization (right). The different colors represent different momenta. The left panel indicates a clear third order angular dependence, which also depends on the momentum. In the right panel, all angular dependencies almost disappear.

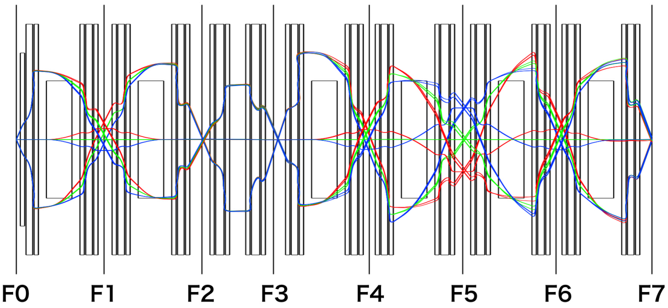

Fig. 1. Calculated horizontal trajectories based on third-order matrix elements by simulation code. Blue, green, and yerrow correspond to +1.0%, 0.0% and −1.0% of deviations, respectively. The sextupole magnets are also taken into account in the calculation.

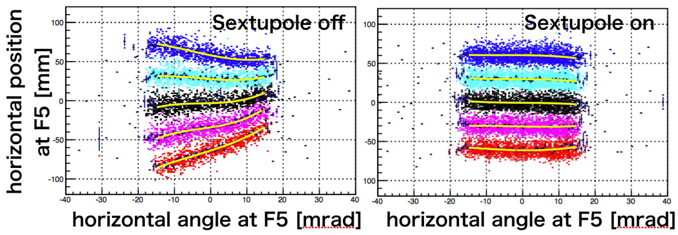

Fig. 2. Position and angle correlation at F5 focal plane. Blue, sky blue, black, pink, and red correspond to the deviations of +1.0%, +0.5%, 0.0%, −0.5%, and −1.0%, respectively. (Left) All of the sextupole magnets are off. (Right) All of the sextupole magnets are optimized.

In conclusion, we successfully controlled the aberrations using the sextupoles by maintaining strict conditions of symmetry. After optimization, dominant aberrations were clearly corrected. This study is a part of our work to develop a dispersion-matched optical system of SRC - BigRIPS. We performed another test experiment to study the optical properties between SRC and F0 in June 2018 as found in Ref. 4).

*1 RIKEN Nishina Center
*2 GSI Helmholtzzentrum für Schwerionenforschung GmbH
*3 Department of physics, Kyoto University
*4 CNS, University of Tokyo

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