ONE POSSIBLE SOUECE OF NON-STRUCTURE OCTUPOLE RESONANCE OTHER THAN OCTUPOLE IMPERFECTION

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Abstract

One possible source of a non-structure octupole resonance at NewSUBARU is a combination of the systematic sextupole and the linear imperfection. The horizontal octupole resonance almost disappeared when we turned the systematic sextupoles off. The same resonance became weaker by a beam alignment, which would have reduced the linear imperfection, with the sextupoles turned on. We also shows the result of the tracking simulation which support the assumption.

INTRODUCTION

The 1.5 GeV electron storage ring NewSUBARU [1] has been constructed in the SPring-8 site in 1998. It shares the 1.0 GeV linac of SPring-8 [2] with the Synchrotron as an injector. The ring is a racetrack type with the circumference of 119 m and has two 14 m long (LSS) and four 4 m long (SSS) straight sections. The ring has six bending cells, which are modified DBA. Main parameters of the ring are listed in Table I. Figure 1 shows the lay-out of the quadrupole and sextupole magnets in 1/4 of the ring and Figure 2 shows the horizontal beta function β_X and the dispersion function η.

The operating point is optimized for the long lifetime and is set at ν_X=6.30, ν_Y=2.23. Here ν_X and ν_Y are horizontal and vertical tune. The chromatic tune spread in the tune diagram is shown in Fig. 3. The working area is limited by four resonance lines, $3\nu_X$=19, $4\nu_Y$=25, ν_X -ν_Y=4 and ν_X -$2\nu_Y$=2. The subject of this article is the non-structure octupole resonance, $4\nu_X$=25.

Table I: Main parameters of the NewSUBARU

Electron Energy	0.5 - 1.5 GeV
Injection Energy	1.0 GeV
Circumference	118.731 m
Type of Bending cell	modified DBA
Number of Bending Cell	6
RF Frequency	499.956 MHz
Harmonic Number	198
Maximum Stored Current	500 mA /ring
Betatron Tune ν_x /ν_y	6.30 / 2.23
Chromaticity ξ_x /ξ_y	3.2 / 5.8
Natural Emittance at 1 GeV	38 nm
Natural Energy Spread at 1 GeV	0.047%

At the present it is recognized that a source of the multi-pole resonance is not always a magnet of corresponding polar multiplicity. One example is a space charge induced structure resonance, such as Montague's resonance [3] and a super structure resonance [4, 5]. The space charge force produces also a non-structure resonance when a quadrupole imperfection exists [6-9]. The other is a down-feeding effect. In most synchrotrons a main source of the quadrupole resonance is not quadrupole magnets themselves, but is a orbit displacement at a sextupole magnet. A non-symmetric sextupole, in other word a sextupole imperfection, produces a momentum dependent quadrupole resonance [10,11]. If we tell about the octupole resonance, there are many kinds of possible sources.

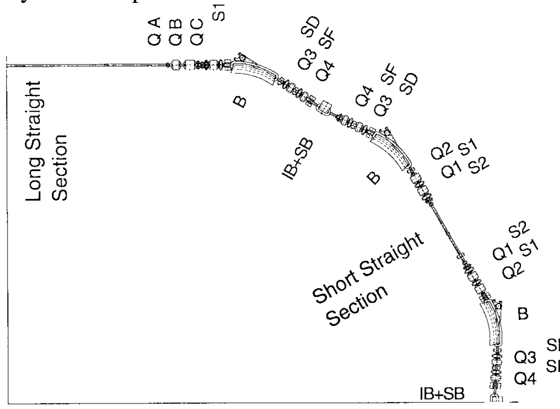


Figure 1: Quadrupole and sextupole configuration of NewSUBARU, magnets in 1/4 of the ring.

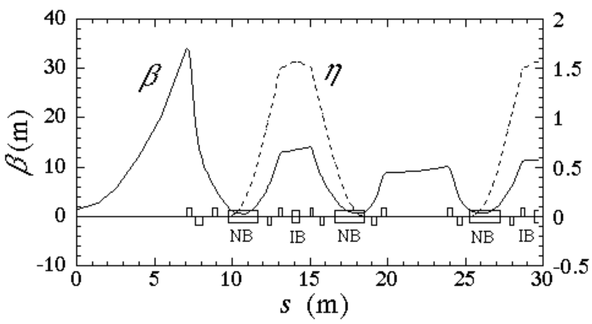


Figure 2: Horizontal beta function (β) and dispersion function (η) of 1/4 of NewSUBARU ring.

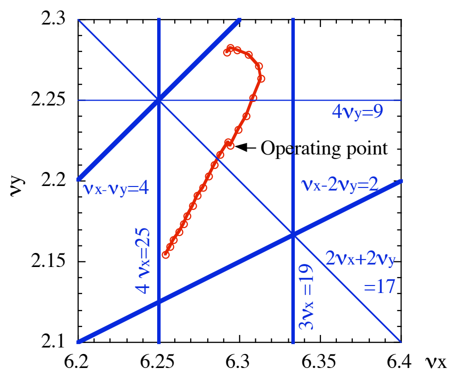


Figure 3: Chromatic tune spread for the full momentum acceptance.

OBSERVATION OF THE OCTUPOLE RESONANCE AT NEWSUBARU

At NewSUBARU we observed a considerable reduction of beam lifetime at the non-structure octupole resonance, $4\nu_y$=25, although the ring has no intentional octupole component. The other octupole resonances near by $4\nu_y$=9 and $2\nu_x+2\nu_y$=17 were less harmful. The dependence of the beam lifetime on the horizontal tune is shown in Figure 4. It looked strange that the resonance almost disappeared by turning off the sextupole magnets. One possibility of the resonance source was an anomaly, for example a miss-winding, of a sextupole magnet. However to the present, we could not find any anomaly in the magnets. The other possibility was a combination of a quadrupole imperfection and the sextupole magnet system.

After we recognized the orbit displacement as large as 1mm or more [12], we have proceeded the beam-based alignment. After the alignment, although its accuracy was still at the 0.4mm level, we measured the beam lifetime near the resonance. The result is shown in Figure 5. It looked that the resonance became weaker by the alignment. This result supports our assumption on the resonance source.

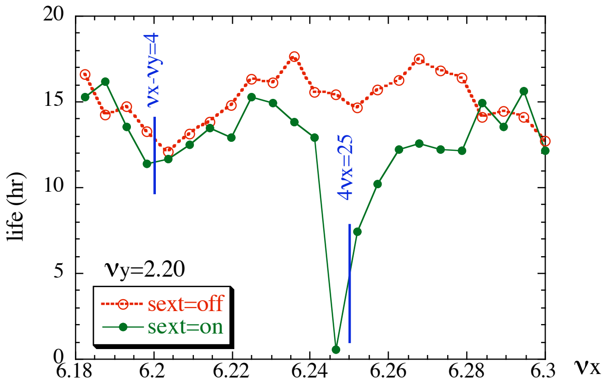


Figure 4: Dependence of beam lifetime on the horizontal tune with sextupoles turned on (solid line) and off (broken line).

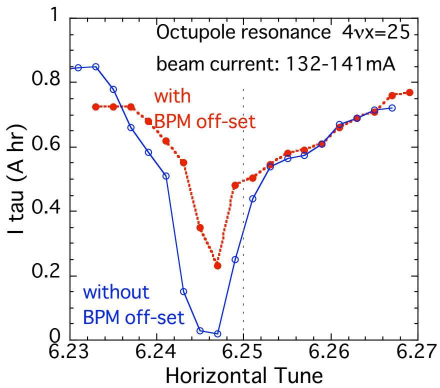
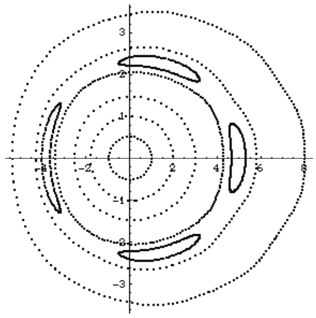


Figure 5: Dependence of beam lifetime on the horizontal tune before (solid line) and after (doted line) the alignment. I-tau is the product of the stored current and the lifetime.

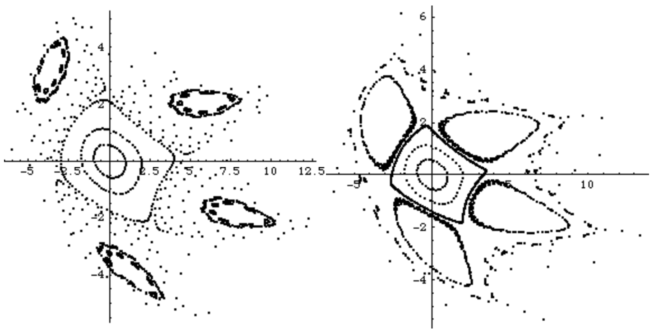
SIMULATION

We confirmed a possibility on the source of the octupole resonance by a simulation. The simulation program is a simple hand-made, single particle tracking program in horizontal direction. The assumed lattice and the strength of the sextupoles were those of NewSUBARU.



ν_X=6.2576.

Figure 6: Horizontal phase space plot at the center of the long straight section in the lattice with no quadrupole perturbation. The horizontal axis is x (mm) and the vertical axis x' is (mrad.), respectively.



(a) ν_X=6.2622 (b) ν_X=6.2576

(c) ν_X=6.2534 (d) ν_X=6.2496

Figure 7: Horizontal phase space plot at the center of the long straight section with conditions of four horizontal tunes. One perturbation quadrupole ($\Delta\nu_X$=–0.04) is introduced in the lattice. The horizontal axis is x (mm) and the vertical axis is x' (mrad.), respectively.

Figure 6 is the phase space plot with no quadrupole perturbation. The weak octupole resonance, which we did not have expected, was maybe produced by an error of the calculation. The phase space plot with a quadrupole perturbation at some horizontal tunes are shown in Figure

7. Because we have no information on the horizontal imperfection, we set one thin quadrupole component at one of the short straight sections as a perturbation. It produced a horizontal tune shift of $\Delta\nu_X$=–0.04. As we had expected, the octupole resonance became stronger.

Qualitatively the result is not surprising. A combination of more than one sextupole components has an octupole component, which means that the ring has the octupole harmonic components of periodicity of the lattice structure. We can estimate the m-th non-structure octupole component from the strength of the strong n-th structural octupole component and the quadrupole perturbation [9]. It obeys a simple scaling law,

$$\left|F_m\right| = \left|\frac{8\Delta\nu}{n-m}F_n\right|. \qquad (1)$$

Here F_n and F_m are the m-th and n-th harmonic octupole components and the $\Delta\nu$ is the strength of the quadrupole perturbation expressed by a tune shift. In this case, m=25 and the structure resonance nearby is n=24.

DISCUSSION

It is well known that a worse alignment reduces dynamic aperture. This report shows that a worse alignment can produce a non-structure resonance. However this is not a proof for $4\nu_X$=25 at NewSUBARU.

We do not reject other possibilities at the present. An interference of the sextupole magnets with the other magnets nearby can produces an edge field with an octupole component. Anyway we do not have accurate parameters of all elements of the ring, including the multi-pole imperfections. For example, Figures 4 and 5 suggest that the amplitude dependent tune shift was positive, however the calculated shift was negative (Figures 6 and 7).

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