Summary of requirements on Q-BPM in the ATF2

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Abstract

We tried to summarize the requirements of Q-BPM from various aspects. The resolution and the accuracy are required to be 100 nm and a few μm, respectively. And the alignment precision is 100 μm. These shold not be confused in the discussion.

1 Introduction

It has been simply described that the resolution of Q-BPM is required to be better than 100 nm. More detailed description is necessary to actually design the system including the installation/alignment and stability issues. When we discuss about these items, the discussion often blows up because of the difference in each member's understanding of the requirement.

In this report, I try to clearlify the requirement in my understanding. Comments are welcome. Justification from optics group, inputs from magnet group, etc. are needed.

2 Accuracy of BPM

In order to achieve the goal of tiny spot size at the IP, beam orbit has to be on the field center of all quadrupole magnets within a few μm. Otherwise beam suffers an undesired kick, which dilutes the spot size. To do the orbit tuning,

- BPMs which have better than a few μm accuracy are necessary. It means that the pulse-by-pulse outputs of the BPM system, after all online analysis process, should be reliable within a few μm error including all the random and systematic errors.
  - Beam intensity change should not affect the outputs of the beam position. Its effect must be removed by the online analysis over, say $0.2 \sim 1.2 \times 10^{10}$ e/bunch intensity range.
  - Gain (calibration factor) stability (or monitoring) is also important to realize the accuracy over the full range.
- The field center of the magnets should be known in better than the precision also (requirement on the accuracy of BBA). The accuracy of BBA requires to have a few μm resolution BPM.
  - Relative position between the field center of magnets and the electrical center of BPM has to have a good stability (a few μm) during beam operation. More specific, typical time scale considering here should be the interval of BBAs (a few days?).

3 Resolution of BPM

In order to achieve the goal of beam position stability at the IP, beam orbit (or individual motion of magnets) must be stable within 100 nm (typically other than final magnets).

- To measure the beam jitter and find out its source, BPM should be able to measure pulse-by-pulse 100 nm orbit difference. It is not necessary to have a long term stability in this level.

- It seems that a set of magnet and its BPM can be treated as a monolithic object (stable within 100 nm level) at least for the short time scale (∼10 seconds) if they are attached rigidly. So the mechanical system should not be the problem for this aspect.
- The amplifier noise limit of the electronics should be lower than 100 nm beam offset signal. This has been proved already.
- The residual correlation to the beam intensity jitter should be smaller than 100 nm in a typical beam condition. Here we assume typical (a little worse than the best case) intensity jitter to be 20%. Even under the intensity jitter, BPM should be able to measure the real beam position jitter better than 100 nm resolution.

4 Stability of BPM

The relative position between the field center of the magnet and the electrical center of the BPM needs to be stable during the beam operation.

- Mechanical stability between the magnet and the BPM.
  - BPM will be rigidly attached on the magnet surface. The magnets have a mover support to align the magnet on the beam and to calibrate the BPM. The mount system of the BPM should be stiff enougth against the mechanical stress due to the mover motion (for example distortion in the bellows chamber). This has been proved for the most simple BPM adapter's case.
  - Turning on/off (or changing the current) should not change the position of the BPM. The displacement of the magnet's poles in turning on/off has been measured to be smaller than 2 μm.
- Mechanical and field stability of the magnet.
  - The stability of the magnet's field center with respect to the mechanical center also has to be better than a few μm for a typical time scale of $\sim$ a day.
- Mechanical and field stability of the BPM.
  - The electrical center of the cavity and the mechanical outer shape have a good stability. Even if we attenuate the signal to have a larger range, it does not change the electrical center. These are the most important advantages in using the cavity BPM.
- Stability as a cavity.
  - Mechanical and thermal stress during the beam operation should not change the properties of the BPM as an rf cavity. For example, frequency and coupling between the two transverse modes etc. should not be changed after installation.

5 Alignment of BPM

The range of the BPM will be determined by the saturation of the detection electronics. The range to keep the best resolution will be ± 200 μm. Even outside of this range, with an analysis technique, it is possible to measure the beam position although the resolution will be worsened. The field center of the magnet, the nominal position of the beam, should be around the center of the best resolution region.

- It has been proved that the electrical center of the BPM coincides with the mechanical center of the outer shape within 10 μm precision. The outer shape can be used as a good reference.
- The initial alignment of the BPM will be done with respect to the mechanical center of the magnet (referring the pole tips).

- The accuracy of the agreement between the mechanical and the field center of the magnet is not well known (at least for me). Here I assume it to be around 100 μm.
- If a misalignment larger than 100 μm was found after beam commissioning (by BBA), it will be possible to realign during maintainance period. 100 μm level of relative adjustment seems not so difficult by a shim, for example.