ELECTRON BEAM MOTION OBSERVED IN INFRARED SYNCHROTRON RADIATION AT NSRRC

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Abstract

Noise existing between 1000 to 4000 cm^{-1} in FTIR spectrum is degrading the signal to noise ratio in infrared (IR) microscopy beam line at SRRC. This is mainly because the interferometer detection is very sensitive to the electron beam motion. Through the RF modulation, the noise spectrum of the infrared interferometry was observed to change as the electron beam motion was modulated. Some of the noise sources were identified in terms of electron beam motion. The analysis indicated that their contribution decided the performance of the IR synchrotron radiation.

INTRODUCTION

Noise generated by the electron beam in storage ring has been regarded as a hurdle of enhancing the performance of IR beam line. It has been known that the IR noise was very sensitive to the mechanical vibration, electrical system and electron beam motion etc. [1,2,3]. Over the past years, these issues were readily improved by adding the active mirror feedback system, replacing the master oscillation and adjusting the power supply, etc., at several IR beamlines. Efforts of improving the S/N ratio of IR beam line at NSRRC, Taiwan light source, were given by tracing the noise from IR-related system, including mechanical and electronic systems. A considerable achievement was given by reducing its RMS of IR noise down to 0.03% over the mid-IR region.

The IR signal affected by the electron beam motion took a special care at ALS and BESSY II over the past years [4,5], due to some behaviors in IR beamline were still an enigma. Interest of tracing the IR noise generated by the electron beam motion is given by observing the beam motion and IR spectrum at NSRRC. According to the observation at IR beamline on the last quarter season, a statistics of RMS in IR spectrum is showed in Fig. 1. As can be seen, the performance of IR beamline is quite similar for both high (~190mA) and low (~100mA) beam current. However, the IR beamline performance became worse during some operation periods. Particularly, after the shut down period, the IR noise was growing up and the beamline performance became poor. The situation was usually improved after 3 to 7-days user-shift operation. The beam spectrum taken from the storage ring was also analyzed during the observed period. The consistency of the beam spectrum indicated that the spectrum was not sensitive enough for detecting a small electron beam motion, which damaged the IR beam quality. How to find out the relation of IR noise with the small beam motion could be important role at the early stage of improving the IR beamline performance at NSRRC.

In this study, we observed the IR beamline spectrum via adjusting the RF modulation. As it has been well known, the RF modulation is one of the mechanisms of stabilizing the electron beam motion. Through the RF modulation system, we observed that some of IR noises came from the beam instability motion.

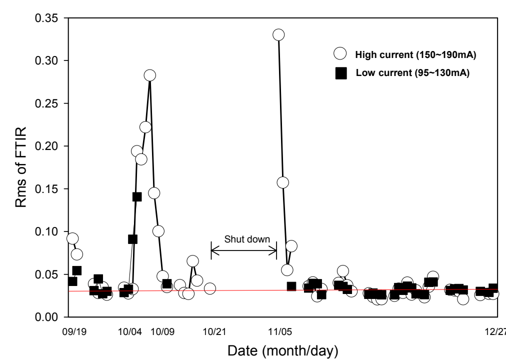


Figure 1: The RMS of IR spectra at transmittance mode

IR SIGNAL MEASUREMENT SETUP

The IR beamline has been developed at the National Synchrotron Radiation Research Center (NSRRC). As shown in Fig. 2, this beamline collects 70 x 35 mrad of synchrotron radiation in the horizontal and vertical directions, respectively, and covers a wavelength range from 2 to 30 μm. The optical design consists of one water-cooled plane mirror, two high-order corrected polynomial bendable mirrors and a set of steering and collimating mirrors. For the consideration of vibration, the first mirror is 45 degree face-downward and its support is fixed to massive dipole magnet. In order to focus effectively the extended arc source of bending magnet, a newly special designed optical system including so-called “Kirkpatrick-Baez” mirrors which use two high-order polynomial mirrors has been adopted, designed and fabricated. The average brightness of this beamline is found to be greater than 10^{16} photons/sec/0.1%bw/mm^2/ 200mA. . A wedged CVD diamond window is used to separate the up-stream UHV section from the down-stream low vacuum section. Three off-axis paraboloid mirrors of different focal lengths are employed to facilitate different experimental setups which require different IR objectives. Table 1 lists the parameters of the mirror elements adopted in our IR beamline. The beamline has been installed, commissioned and now is open to the all users.

In IR noise study, the spectrum was taken through the Nicolet 860 FTIR bench and a continuum IR microscope. The scanning speed of the interferometer is down to the lowest (0.00158mm/sec). The interferometer signal is then taken from the spectrum analyzer.

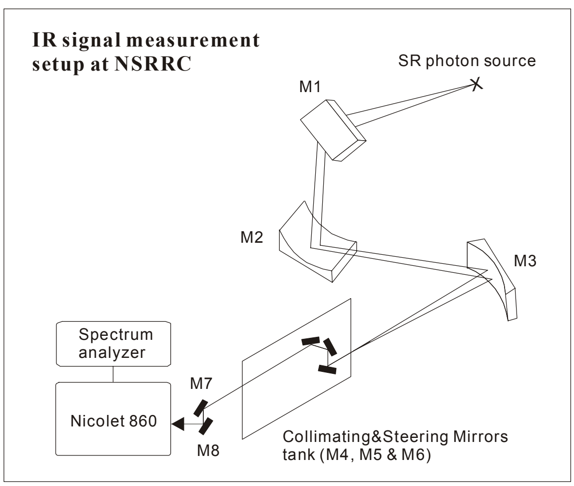


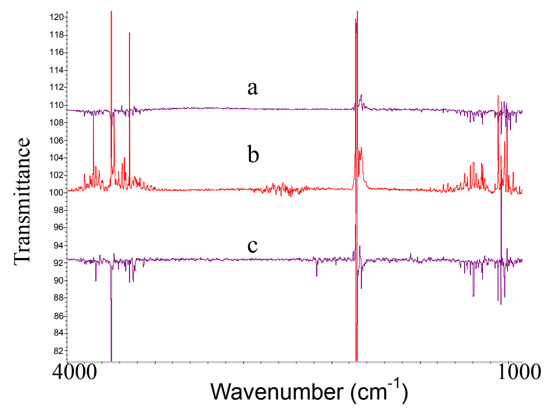
Figure 2: Schematic Diagram of Optical Layout of IR beamline at NSRRC

Table 1: The optical parameter of 14A IR Beamline (70mrad x 30 mrad)

Mirror PARAMETER	M1	M2	M3	M4	M5
Source-Element distance (mm)	1206.8	1706.8	3776.8	7981	8345
eviation angle (°)	90	90	100	9.5	99.5
Facing	Downward	Upward	Horizontal	Upward	Downward
Coating	Au	Au	Au	Ag(or Au)	Ag(or Au)
Distance (mm)	---	r1=1706.8 r2=5670	r1=3776.8 r2=3600	r1=604 .2 r2=∞	---

SPECTRAL NOISE STUDY

Investigation of IR noise generated by electron beam motion, we adjusted the RF voltage modulation to observe the IR noise. As it has been known, the modulation of RF system is an important mechanism of stabilizing beam motion in the storage ring. At NSRRC, RF voltage modulation is operated by a sinusoidal wave with 51.08kHz modulation frequency. The beam stability $\Delta I / I_0$ lower than 0.2% takes 80% at the user shift. Under such a condition, the IR spectrum was observed by fixing the moving mirror in the interferometer and measured by the spectrum analyzer on the output of MCT detector. Fig. 3 demonstrates the RMS of FTIR spectrum over the mid-IR is 0.024% at 122mA. The measurement also taken by switching off the RF modulation system. A visible beam shacking was immediately observed on beam monitor. The RMS of FTIR spectrum raises to 0.23% at 119 mA. This is more



a. 0.024%@122mA (RF modulation b. on)
b. 0.23% @119mA(RF modulation off)
c. 0.18% @25mA (RF modulation off)

Figure 3: The FTIR spectrum

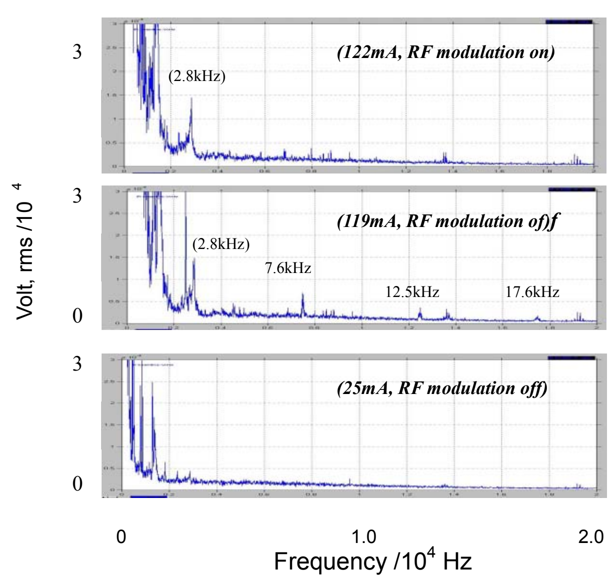


Figure 4: The IR spectrum.taken from the MCT detector

one order increasing in IR noise . Comparing the results shown in Figs. 4, 2.8kHz noise always exists in IR beamline Obviously, it doesn't matter with the beam motion. As can be seen in Fig. 4, the peaks at 7.6kHz, 12.5kHz and 17.6kHz were come into view after the RF modulation off. It indicates that these noises were generated by the electron beam motion but suppressed by the RF modulation. In order to further demonstrate the effect of beam instability on IR beam line, the beam current was down to 25mA, where the electron beam was observable stability without the RF voltage modulation. The RMS is shifted to 0.18% at 25mA, The noise peaks including 2.8kHz disappear at the stable beam motion. It can be said that 2.8kHz noise peak is current dependent. Very flat noise figure implied that part of IR noise indeed generated by the electron beam motion.

CONCLUSIONS

IR noise driven by the electron beam instability has been identified in terms of the RF voltage modulation. As the case study at NSRRC, some specific IR noises (eg., 2.8kHz) are excited by the electron beam after a threshold current is reached. They are not affected by the beam instability. However, some other IR noises are driven by the beam instability and reduced after the beam is stabilized. The sources of exciting these IR noises through the beam motion are still unknown. They could be generated by the IR-related systems, merged into the electron beam motion and then spoil the IR signal. The further study of IR noise could need to trace the sources step by step in the whole system and analysis their effects. Additionally, due to the IR noise is very sensitive to the beam motion, the analysis may be used as a tool of diagnosing the beam quality.

ACKNOWLEDGEMENTS

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