

A DIAMOND DETECTOR TEST BENCH TO ASSESS THE S2C2 BEAM CHARACTERISTICS

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Abstract

During the assembly and initial start-up of the superconducting synchro-cyclotron (S2C2) in the manufacturing hall at Ion Beam Applications (IBA), some key properties of the extracted beam have to be validated. A new setup was developed to assess the beam direction out of the S2C2, the beam energy variation as a function of main coil current and main coil position, and the time structure of the beam. In the future, the setup will be extended with an emittance slit. The beam detector in this setup is a sensitive "poly-crystalline diamond detector" (pCVD), which requires small amounts of beam from which a maximum amount of information can be extracted. The high sensitivity and versatility of the detector are important aspects in order to limit the activation of the S2C2 during in-factory beam tests.

INTRODUCTION

The activation of the S2C2 during in-factory beam tests has to be limited to an absolute minimum to facilitate the transport of the accelerator to the installation site. Therefore, a sensitive and versatile detector is needed to extract as much information as possible at a minimum beam intensity. Therefore, a new setup was developed which measures the beam direction, size and divergence and the beam energy variation with main coil current and horizontal main coil position.

THE EXPERIMENTAL SETUP

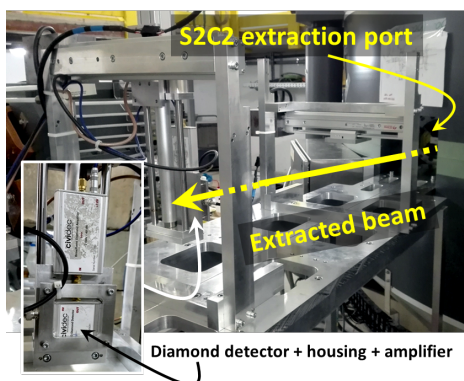


Figure 1: The diamond detector setup installed on a table directly connected on the exit port of the S2C2. The support of the diamond detector can be moved to fixed distances from the exit port and the detector itself can move continuously both horizontally and vertically in the beam. An additional support is foreseen to install an emittance slit.

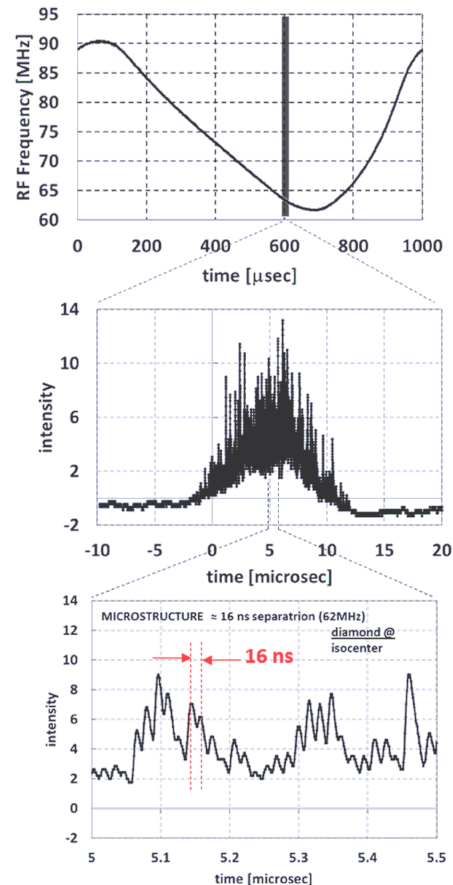


Figure 2: (top) 1 period of the RF frequency sweep in the S2C2. Extraction of the beam happens around 63 MHz. (middle) The diamond detector signal. (bottom) A zoom on the diamond detector signal. Individual proton bunches on the RF wave are visible. The bunches come out at a frequency of 63 MHz, or with a periodicity of 16 ns.

The beam detector is a "poly-crystalline diamond detector" (pCVD, see [1]) with an active surface of $10 \text{ mm}^2 \times 10 \text{ mm}^2$ and a thickness of 500 μm . Protons of 230 MeV loose about 400 keV in the detector. This detector is typically used as beam loss monitor or for time-of-flight measurements. In our case, the good timing properties (sharp rising time and fast fall-time) and its high sensitivity make it an excellent detector to measure small intensity pulses from the S2C2. Figure 1 shows the full setup, installed on the exit port of the S2C2. A support structure, carrying the diamond detector, can be installed at fixed distances from the exit port. The detector itself is scanned continuously both horizontally as vertically in the beam path. A second support structure is foreseen to install an emittance slit.

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TIMING AND DETECTOR SIGNAL

Figure 2 shows the timing of the S2C2 beam. For a full explanation of the operational principles of the S2C2, see [2]. The top figure shows 1 period of the RF frequency sweep as a function of time. The beam capture in the central region happens around 87.5 MHz, whereas the extraction happens around 63.0 MHz, depending on the magnetic field configuration. The latter depends essentially on the horizontal position of the superconducting main coil. The middle part of Fig. 2 shows the diamond detector signal. The beam pulse lasts for about 10 μs and appears around the frequency of 63 MHz. The bottom figure shows a zoom in the diamond detector signal, showing the individual proton bunches on the RF wave. Since the RF frequency is around 63 MHz, the periodicity of the micro-bunches is around 16 ns.

EXTRACTION FREQUENCY

A Fourier transform of the diamond detector signal is shown in Fig. 3. The extraction frequency of the proton bunches is clearly visible around 63 MHz. When the super-

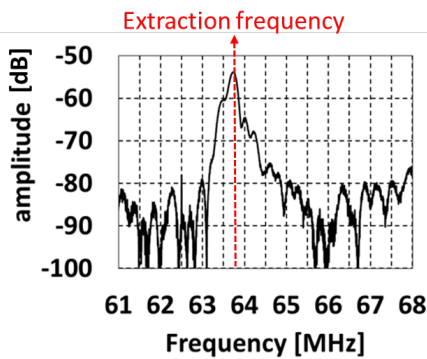


Figure 3: Zoom in the Fourier transform of the diamond signal. A peak is observed at the extraction frequency of the S2C2.

conducting main coil is shifted horizontally, the extracted beam energy will change, as was shown in [2]. The extracted beam energy will also change when the main coil current is changed. Measured maps were used to assess this change in energy and revolution frequency of the protons on their last stable closed orbit as a function of the main coil current and position. The energy change is 450 keV per additional Ampere in the coil and the frequency change of the last stable closed orbit is 43 kHz per additional Ampere. The revolution frequency of the last stable closed proton orbit changes with about 100 kHz per mm of coil shift. Both frequency changes have been measured and correspond very well with the calculations, as is shown in Fig. 4.

BEAM SIZE AND DIRECTION

The measured horizontal intensity profiles of the extracted beam are shown in Fig. 5 as a function of distance from the extraction port of the S2C2. As can be seen, the unfocused beam out of the S2C2 is around 50 mm wide. From the

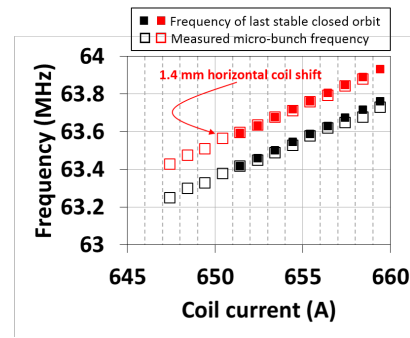


Figure 4: The measured and calculated frequency of the extracted proton microbunches, as a function of main coil current and position.

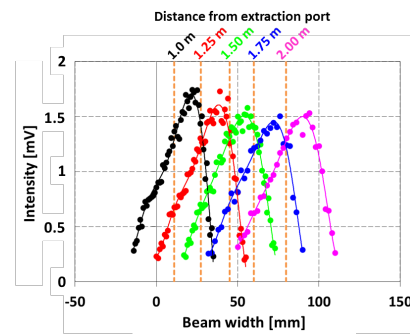


Figure 5: The measured horizontal intensity profiles of the extracted beam as a function of distance from the exit port.

increase in beam width as a function of distance, the horizontal divergence can be derived and is measured to be around 10 mrad. From the shifted center of the beam, the exact beam direction can be determined. Figure 6 shows a comparison of the measured and calculated beam widths.

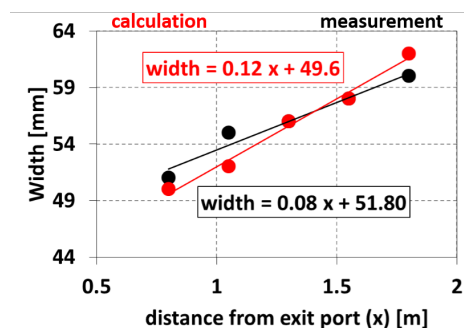


Figure 6: Comparison of the calculated and measured horizontal width of the extracted beam from the S2C2.

CONCLUSION

A new setup, based on a high sensitivity and fast diamond detector, to assess the beam characteristics (beam energy as a function of main coil current, beam direction and size and temporal profile) of the S2C2 has been developed and commissioned successfully at IBA.

REFERENCES

- [1] Cividec, <https://cividec.at>
- [2] J. Van de Walle *et al.*, "The S2C2 from source to extraction", presented at Cyclotrons'16, Zurich, Switzerland, Sep. 2016, paper THB01, this conference.