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) in Belgium, some key properties of the accelerator have to be validated. A new setup was developed to assess the beam direction out of the S2C2, the beam energy (variation) and the time structure. This setup is based on a sensitive diamond detector, which requires small amounts of beam from which a maximum amount of information can be extracted.

EXPERIMENTAL SETUP

The beam detector is a “poly-crystalline diamond detector” with an active surface of 10x10 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.

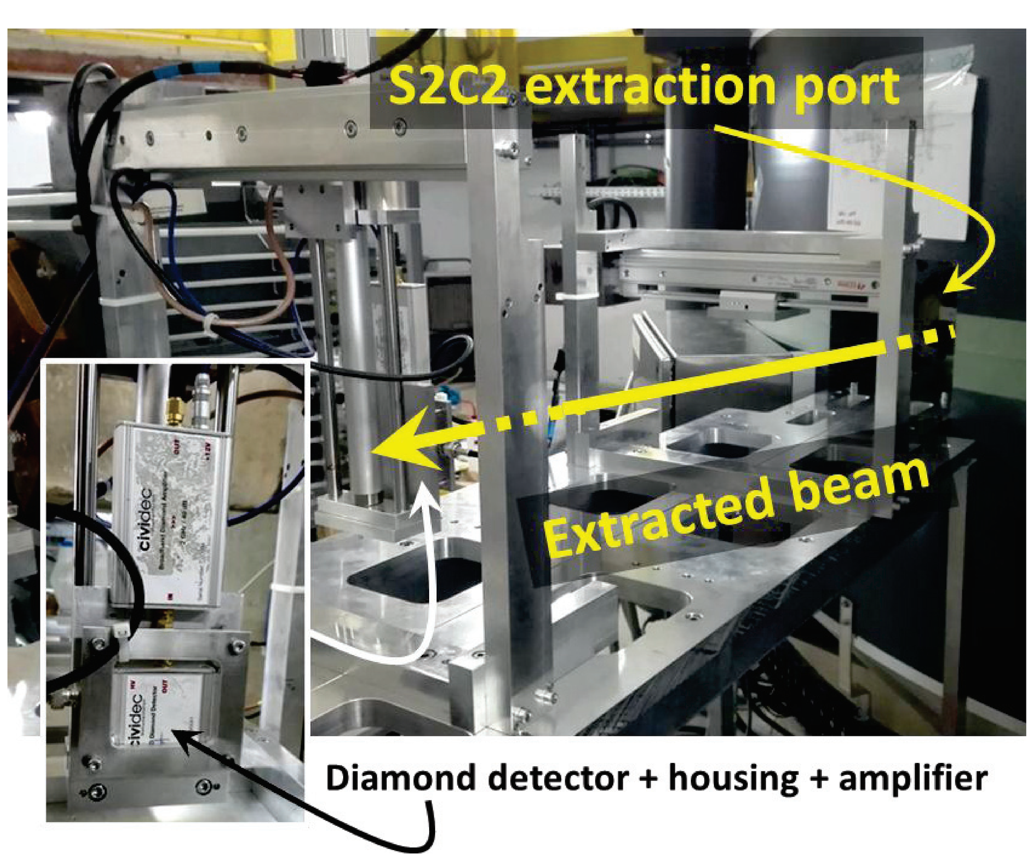

Figure 1: The diamond detector setup installed on a table, which is fixed in the extraction port of the S2C2.

Fig. 1 shows the setup at the exit of the S2C2. The diamond detector can be scanned in the beam both horizontally as vertically. The diamond detector support structure can be positioned at fixed locations after the extraction port (from 0.2 m up to 2 m).

Fig. 2 shows the timing of the S2C2 beam. The top figure shows the RF frequency as a function of time. The beam capture in the central region happens around 87.5 MHz, whereas the extraction happens around 63 MHz, depending on the magnetic field configuration. The zoom around 600 μs shows the detected temporal beam profile, as detected by the diamond detector. The beam pulse lasts for about 10 μs and repeats itself every 1 ms. 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.

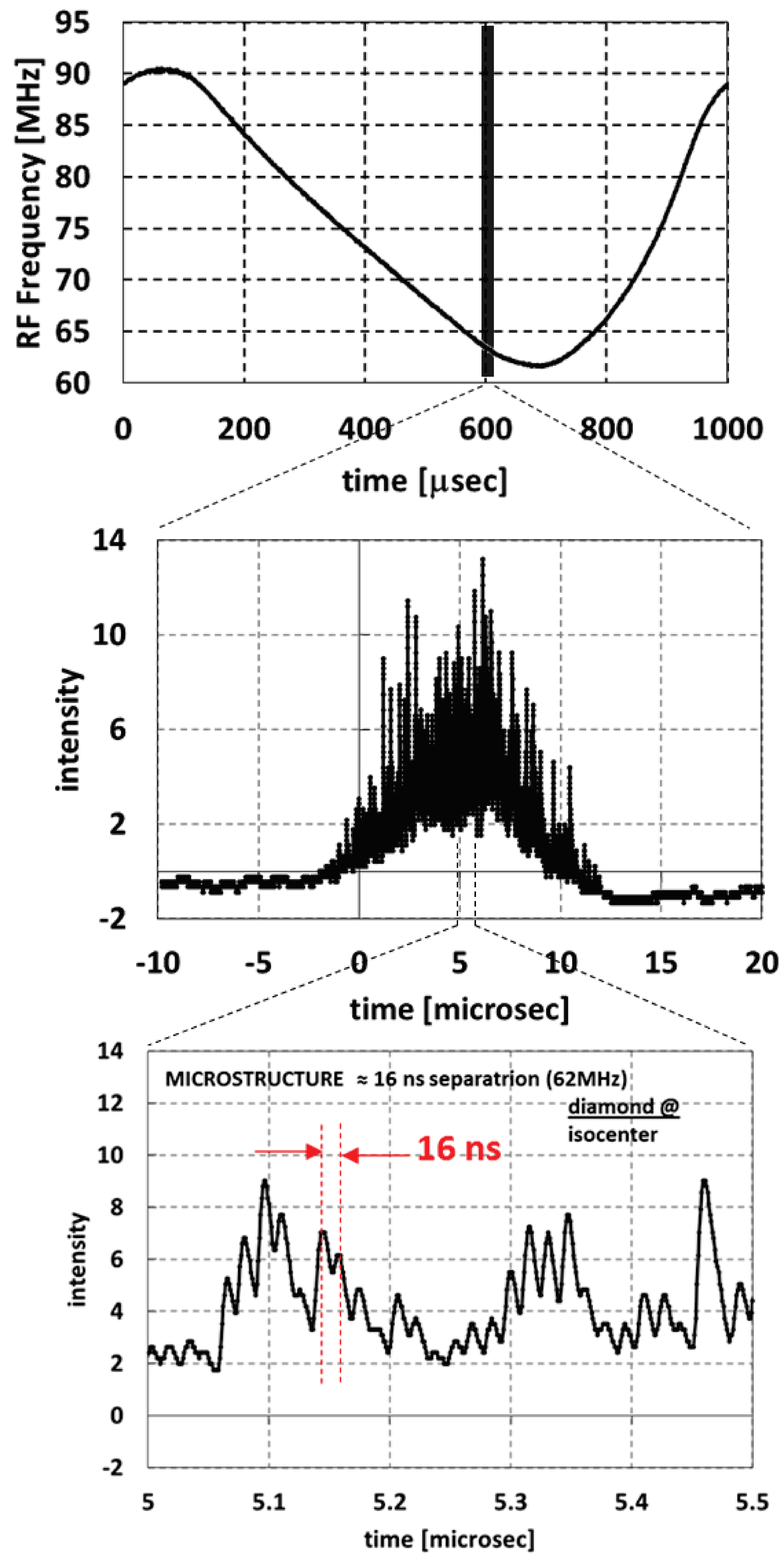

Figure 2 : (top) the RF frequency versus time (middle) the diamond detector signal (bottom) detail of the diamond signal, where the individual proton bunches on the RF wave are visible (63 MHz, 16 ns).

EXTRACTION FREQUENCY

If a Fourier transform is made of the measured diamond signal, a clear peak is observed at the extraction frequency of the proton bunch (see Fig. 2(top) and Fig. 3(top)). If the main coil of the S2C2 is moved horizontally, the extracted energy will change since the $2\nu_r=2$ resonance is reached at a different energy. From a closed orbit analysis in two measured maps with two different main coil positions, we can deduce the revolution frequency of the protons. This has been done for different main coil currents as well. The revolution frequencies of the protons on the last stable closed orbit is shown in Fig. 3 with the filled symbols. We measured the micro-bunch frequency with the Fourier transform of the diamond detector signal, in these two main coil positions and for different coil currents. The detection accuracy of the frequency is down to 10 kHz. The change we see is about 450 keV per additional ampere in the coil, which corresponds to about 43 kHz of frequency change. The shift of the extraction frequency as a function of horizontal coil position is 100 kHz/mm, or 1.4 MeV/mm. This measurement enables us to fine-tune the main coil current to have a well defined energy.

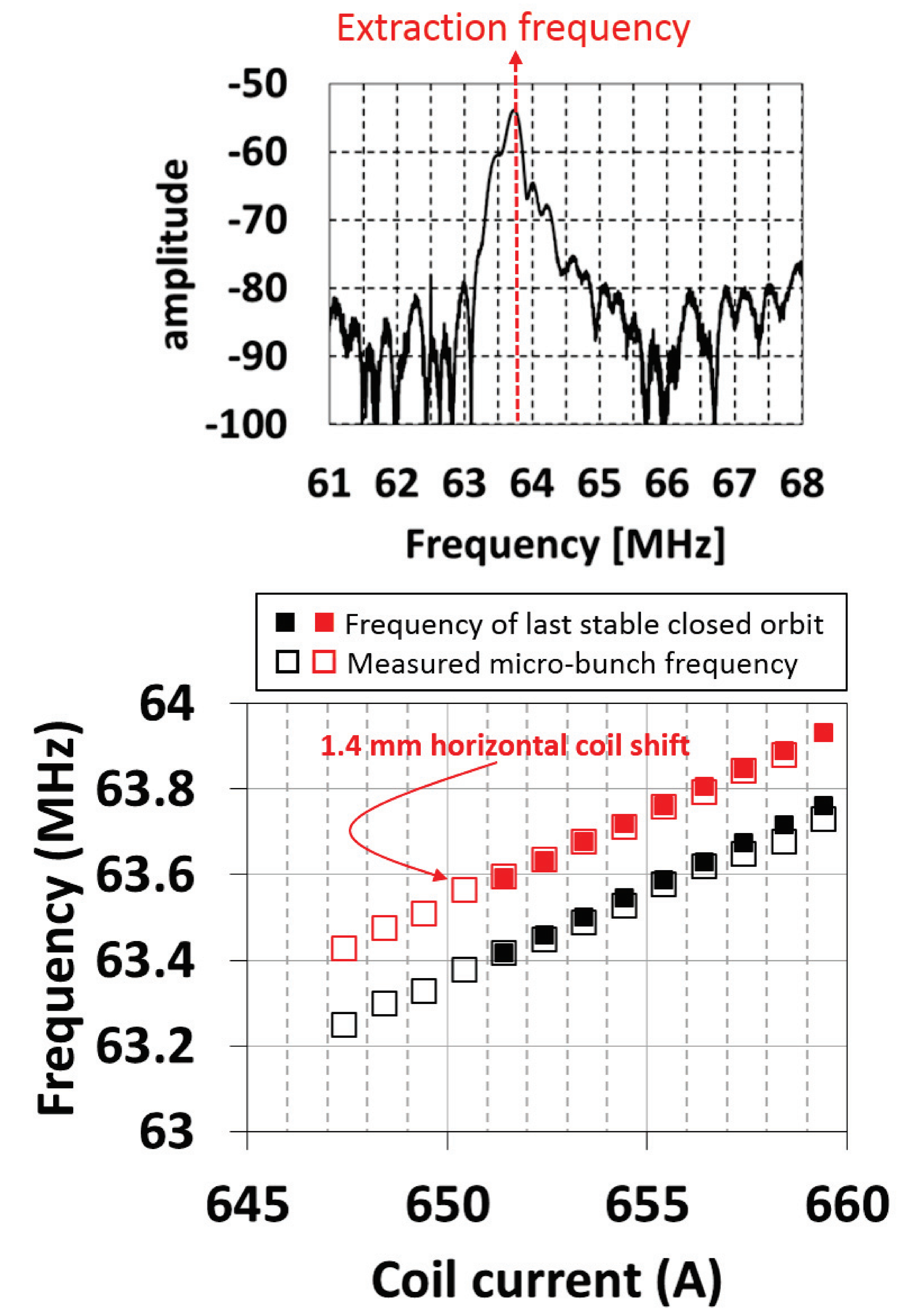

Fig. 3 : (Top) Fourier transform of the diamond signal. (Bottom) The measured extraction frequency for two different main coil positions and as a function of main coil current.

BEAM SIZE AND DIRECTION

The measured horizontal beam profiles of the extracted beam is shown in Fig. 4 for different positions of the support after the extraction port. From these measured profiles, the beam direction, size and divergence can be deduced.

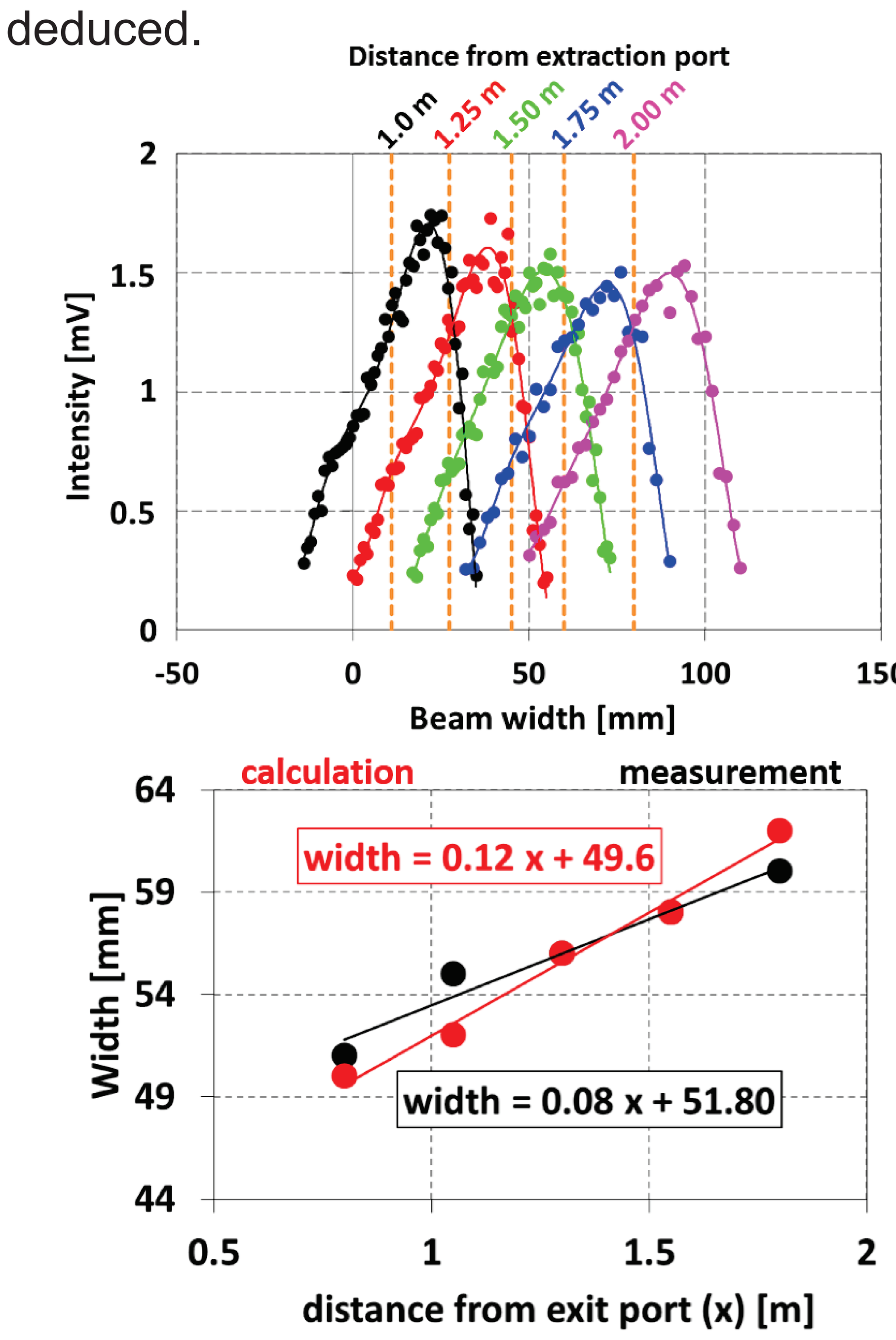

Fig. 4 : (Top) measured horizontal beam sizes of the unfocused beam along its path outside the S2C2. (Bottom) calculated and measured beam widths with fitted divergence.

CONCLUSION

A highly sensitive and versatile setup was developed and tested successfully at the IBA manufacturing facilities to facilitate in-factory beam validation of the S2C2.