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COMMISSIONING OF A MOVABLE BUNCH COMPRESSOR FOR SUB-fs ELECTRON BUNCHES *

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Abstract

We present the first commissioning results of the movable bunch compressor (BC) designed for the ARES linac at DESY. The development and simulated performance has been reported earlier and predicts sub-fs electron bunches with high charge densities. Commissioning results of the injector part of the ARES linac delivered promising beam quality results to achieve these numbers. The bunch compressor system is foreseen to be used to bench mark numerical models for coherent synchrotron radiation (CSR) and space charge (SC) for ultra-short electron bunches. Here we will present first measurements of the dispersion as well as calculations for the longitudinal dispersion. In the future the PolariX transverse deflecting structure (TDS) will be commissioned to fully characterize the ARES electron beam.

ARES OVERVIEW

The ARES linac [1] is an S-band normal conducting linear electron accelerator for research and development of accelerator technology. The main focus lies on the production and characterization of high quality sub-fs electron bunches. Also the injection into laser driven electron acceleration schemes is pursued [2]. ARES is composed of a 1.6 cell gun and two 4 m long traveling wave structures (TWS). A vacuum chamber for exchangeable samples is located downstream of the radio frequency (RF) structures. A matching section comprises six quadrupole magnets and correctors connects to the BC section. The diagnostic line comprises the TDS [3] and dipole spectrometer. At the end of the diagnostic section the beam can be coupled out into air via a 50 μm titanium window. An overview of the installation can be found in another contribution [4].

Two modes of operation for short bunches are possible with the current setup: velocity bunching and magnetic compression. Hybrid Working points taking advantage of both concepts were studied also [5]. For the hybrid and magnetic compression working points the characteristics of the BC are essential. The beam is transported to the BC via the matching section and the longitudinal dispersion of the bunch compressor is adjusted to minimize the bunch length. Non-linearity of the longitudinal momentum correlation, uncorrelated energy spread, SC and CSR [6, 7] can be limiting factors in bunch compression. The development and performance prediction have been published [8].

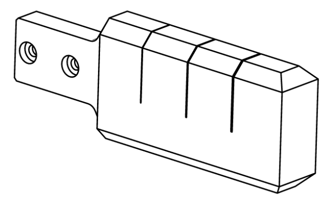

Figure 1: Drawing of the shape collimator blade. At the moment the attached blade has three slit apertures of 0.2 mm, 0.4 mm and 0.6 mm.

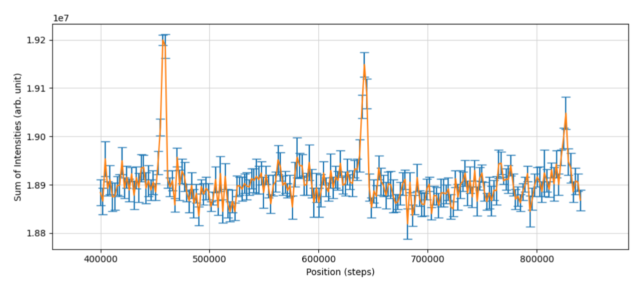

Figure 2: Beam intensity after the bunch compressor vs. position of the collimator mover. The three peaks correspond to the different apertures.

BUNCH COMPRESSOR

The magnetic chicane consists of four dipole magnets of which the two center ones can be moved up to 20 cm out from the center line to achieve large variability in the longitudinal dispersion. An overview of the BC is illustrated in Fig. 3. In between the two center magnets, where transverse dispersion is largest, an aperture collimator is installed to cut the real space of the bunch. A drawing of the collimator blade is shown in Fig. 1. Its function was checked by measuring the intensity on a down stream scintillating screen against the position of its transverse mover. Results are shown in Fig. 2. The collimator can be used to mitigate bunch lengthening from the non-linearity in longitudinal phase space due to RF curvature at the TWSs. A scintillating screen station is installed allowing the measurement of the transverse dispersion between the two center magnets. The first three dipole

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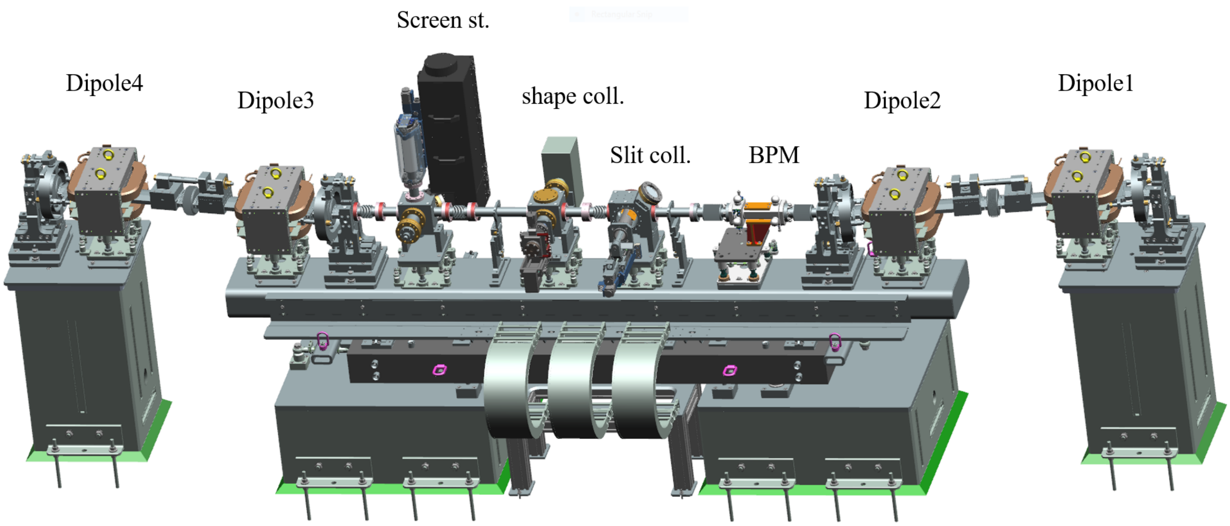

Figure 3: Overview CAD rendering of the movable bunch compressor including the diagnostic devices between the two center dipole magnets: Cavity based beam position monitor (not operational yet), scintillating slit collimator (not installed yet), shape collimator, scintillating screen station. Center magnets and diagnostic devices are located on the movable girder.

magnets are equipped with corrector coils to close the orbit and manage dispersion downstream of the BC section.

Dispersion Measurement

The transverse dispersion inside of the BC is measured using the orbit deviation of the electron beam on the scintillating screen station while the mean momentum of the beam is varied. Momentum variation is achieved by changing the RF power going to the second TWS.

First step is the measurement of the TWS2 RF amplitude against the mean momentum of the beam using the spectrometer dipole. The mean momentum is varied by ca. one percent. Figure 4 shows the result of this calibration measurement. Afterwards a number of momentum sweeps is performed, recording the beam position on the screen station in the middle of the BC. From the momentum calibration and the recorded orbit deviation the transverse dispersion can be calculated. For each momentum sweep a linear fit on the beam position is calculated, where the slope of the fit gives the orbit deviation proportional to the momentum deviation. The resolution of the measurement is limited by the scintillating screen resolution, orbit jitter and drifts during data recording. The residual transverse dispersion appears to be smaller than the resolution. This renders a dispersion compensation infeasible at the moment. The measurement of the transverse dispersion inside of the BC was repeated for a number of current settings for the dipole main coils resulting in sufficiently high transverse dispersion. The strength of the dipoles was calculated from the current to magnetic flux density calibration measured before installation.

A model of the bunch compressor was simulated in ASTRA [9]. Figure 5 shows the measured data and the prediction calculated from the simulation. Table 1 gives the measured and the calculated transverse dispersion and the corresponding calculated longitudinal dispersion. The data shows good agreement within the error bars.

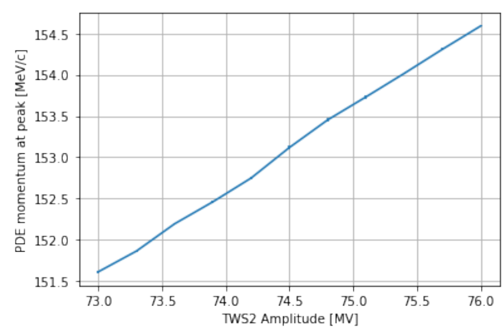

Figure 4: Mean electron beam momentum as measured using spectrometer dipole in dependence of the amplitude of the RF signal of TWS2. The amplitude setting corresponds to the maximum accelerating field strength.

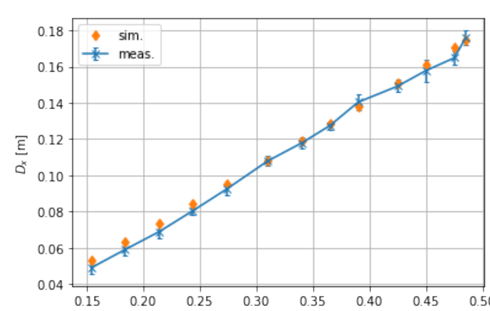

Figure 5: Magnetic flux densities B at the magnet center vs. measured and calculated horizontal dispersion D_x from the ASTRA model. An effective magnetic length of 0.21 m for the dipoles is assumed.

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Table 1: Measured and calculated transverse dispersion D_x, calculated longitudinal dispersion R_{56}

B [T]	meas. D_x [m]	cal. D_x [m]	cal. R_{56} [mm]
0.485	0.176 ± 0.004	0.175	-63.885
0.475	0.165 ± 0.004	0.171	-61.138
0.450	0.158 ± 0.006	0.161	-54.573
0.425	0.149 ± 0.003	0.151	-48.428
0.390	0.140 ± 0.004	0.138	-40.515
0.365	0.127 ± 0.002	0.128	-35.340
0.340	0.118 ± 0.003	0.119	-30.546
0.310	0.108 ± 0.003	0.108	-25.292
0.274	0.092 ± 0.003	0.095	-19.619
0.244	0.080 ± 0.002	0.084	-15.528
0.214	0.069 ± 0.004	0.074	-11.931
0.184	0.059 ± 0.003	0.063	-8.819
0.154	0.049 ± 0.003	0.053	-6.188

CONCLUSION

We performed measurements on the transverse dispersion of the BC. Measured data for the BC corresponds well with numerical modelling. The recently measured beam parameters [10] are promising for achieving high charge density ultra-short electron bunches at ARES in the near future.

OUTLOOK

In the upcoming months additional diagnostic devices will be installed and commissioned at ARES. A number of cavity based beam position monitors [11, 12] along the beam line will help to improve the transverse dispersion measurement. An additional scintillating slit collimator will be installed that allows for fine tuning of the slit width and position. The blades are coated with a scintillating phosphor material enabling the imaging of the cut part of the electron beam. Figure 6 shows a drwaing of this collimator.

The most precise performance verification method will be installed in the form of the PolariX TDS. It will allow for direct bunch length measurements and longitudinal phase space characterization.

In the mean time it is planned to use the titanium vacuum window at the end of the linac to conduct an experiment characterizing the transition radiation generated by the passing electron bunch. If the bunch is short enough, part of the transition radiation that can be detected using a standard silicon based camera will be coherent. This should correspond to a quadratic proportionality of the radiated energy to the charge of the electron bunch. An experimental setup comparable to [13] can be implemented.

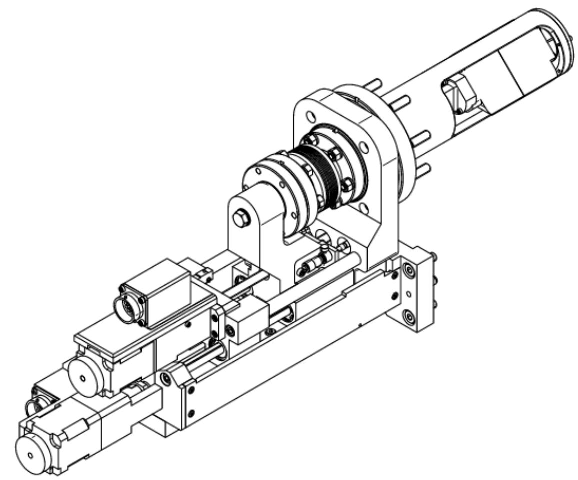

Figure 6: Drawing of the scintillating slit collimator. The two blades can be moved independently to change position and slit size continuously. They are coated with a scintillating material allowing the imaging of the cut part of the beam onto a camera system.

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