TECHNICAL DESIGN CONSIDERATIONS ABOUT THE SINBAD-ARES LINAC

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Abstract

The SINBAD facility (Short and INnovative Bunches and Accelerators at Desy) is foreseen to host various experiments in the field of production of ultra-short electron bunches and novel high gradient acceleration techniques. The SINBAD linac, also called ARES (Accelerator Research experiment at SINBAD), will be a conventional S-band linear RF accelerator allowing the production of low charge (0.5pC - few pC) ultra-short electron bunches (FWHM, length <= 1fs - few fs) with 100 MeV energy.

In this paper we present the current status of the technical design considerations, motivate the foreseen diagnostics for the RF gun commissioning and present examples of foreseen applications.

INTRODUCTION

Particle accelerators are used in many applications such as particle physics and radiation generation. The demand for their compactness and cost efficiency encourages new efforts in the field of research and development (R&D) towards novel high gradient acceleration techniques. The SINBAD facility (Short INnovative Bunches and Accelerators at Desy) [1] is a long-term dedicated accelerator R&D facility currently under construction at DESY. Novel high gradient acceleration techniques are characterized by a short wavelength accelerating gradient, which require the injection of ultra-short electron bunches. SINBAD will profit by the strategy of hosting multiple independent experiments combining the fields of production of ultra-short bunches for ultra-fast science and test of novel high gradient accelerating techniques. The heart of this facility will be the ARES linac, a 100 MeV linac designed to provide sub-fs electron bunches to be injected into novel high gradient accelerating techniques [2].

HIGHLIGHTS ON THE TECHNICAL DESIGN OF THE LINAC

Fig.1 presents the conceptual design of the ARES linac. It will consist of a RF-gun of the same type of the one used at REGAE [3], two 2.998 GHz traveling wave accelerating structures and a bunch compressor operated with a slit between the second and third dipole [4].

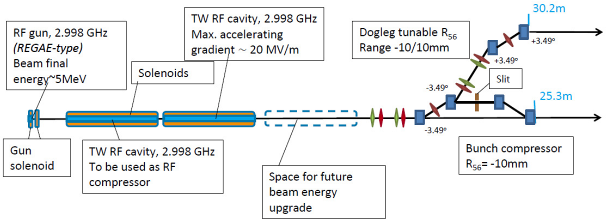

Figure 1: Layout of the ARES accelerator.

RF Gun Region Design

The electrons are extracted by photoemission by a 1 mJ Yb doped laser with a variable FWHM pulse length between 180 fs and 10 ps. This laser system has been successfully procured in 2015 and it is currently installed in a temporary location for preliminary tests. In the baseline version of the linac it is foreseen to use a laser pulse having transversally flat-top and longitudinally Gaussian profile respectively.

Fs level synchronization between the laser and the RF field of the gun will be achievable by implementing the same methods described in [5].

A load lock system will allow for in-vacuum cathode exchange in the RF gun. Both Cs_2Te and metallic cathodes are foreseen to be employed.

A focusing solenoid located at about 46 cm from the cathode will allow the transverse focusing of the low charge bunches (0.5-10pC), having about 5 MeV energy. Moreover a second solenoid located before the RF-gun on axis coaxial coupler will be implemented in the future to allow high quality transport and focusing of beams having charge higher than 10pC.

E-beam Characterization at the RF-gun Exit

The entrance of the first accelerating cavity is located at 2.5m from the cathode. The diagnostics for the beam in the gun region will be located in this area. A first conceptual layout for the integration of the diagnostics with the magnets and vacuum elements is shown in Fig. 2.

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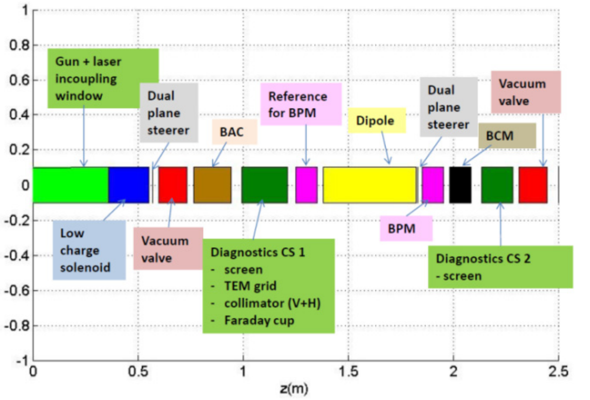

Figure 2: Conceptual layout for the diagnostics integration between the RF-gun and the first travelling wave structure. In the picture many abbreviations have been used: Beam Arrival time Cavity (BAC), Beam Position Monitor (BPM), Beam Current Monitor (BCM).

The first diagnostics section will include a Faraday Cup for the charge measurement, a scintillator screen for the measurement of the transverse spot size, a collimator and a fourth entry possibly hosting a TEM grid for emittance measurements [6]. The second diagnostics section will host a scintillator screen.

Transverse emittance will be also measured via solenoid scans as performed in [7].

A 90deg spectrometer dipole of the same kind of the one used at REGAE will be used for energy and energy spread characterization. To this aim a third diagnostic section will be located in second line, perpendicular to the main one.

For high resolution beam position measurements high-Q Cavity BPMs are under consideration.

RF Stations and Synchronization

Each RF cavity in the ARES linac will be fed by an independent RF station and will be operated with long RF pulses (6µs for the gun RF station, 4.5µs for the linac RF stations).

The position of the linac inside the tunnel shown in Fig.3 has recently been shifted about 2m downstream the tunnel with respect to the initial foreseen location in order to minimize the distance among the cavities, the RF stations and the racks containing parts of the LLRF. This adjustment is necessary for digital feedback regulation in micro-second range. Fig. 4 shows the baseband (down-converted from its resonating frequency) transfer function (TF) from the input to the structure to the energy gain for a SWS (3dB bandwidth initially set to 100 kHz) and TWS with length of 4.2m and about 800 ns fill time; cable latencies are neglected. The maximum achievable feedback gain depends in standard digital feedback loops (PID controller) on the 3dB bandwidth of the plant to be controlled (see Fig. 4) and the sum of all latencies in the feedback loop. Simulations show, that minimizing this latency by shifting the linac stations allows regulating more precisely the amplitude and phase in the linac section in a digital feedback loop.

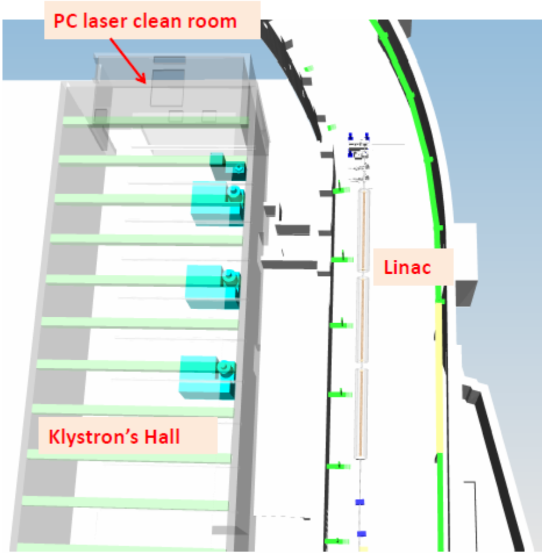

Figure 3: Location of the ARES linac inside the SINBAD tunnel. The figure also shows the location of the klystron's hall containing the RF stations and the position of the photo-cathode laser room. Part of the racks necessary for LLRF will be located in a cellar directly below the current linac position.

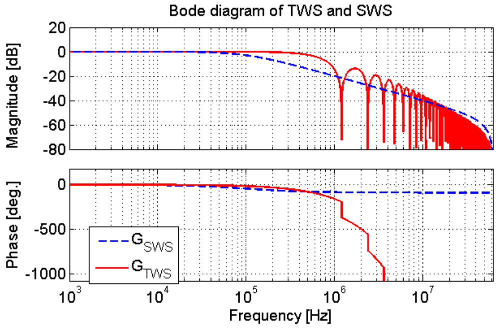

Figure 4: Baseband transfer function around the nominal driving frequency of 2.998 GHz for a standing wave structure (SWS), e.g. the RF gun - dashed line - and traveling wave structure - solid line - used in linac.

APPLICATIONS

The ARES linac will be used as injector to test novel high gradient acceleration methods. Three applications are foreseen at the moment:

1. Injection of electron bunches compressed by using velocity bunching in a THz driven dielectric loaded structure [1,8];
2. Test of dielectric structures realized within the ACHIP project [9];
3. Laser driven plasma wake-field acceleration (LWFA) experiment with external injection [10,11].

Fig. 5 shows the location of the ARES linac inside the SINBAD facility. The feasibility of the planned experiments is supported by the presence of laser laboratories operated by collaborating groups at DESY in the upper side of the facility layout and by the possibility of hosting a future high power laser lab in the central hall of the facility.

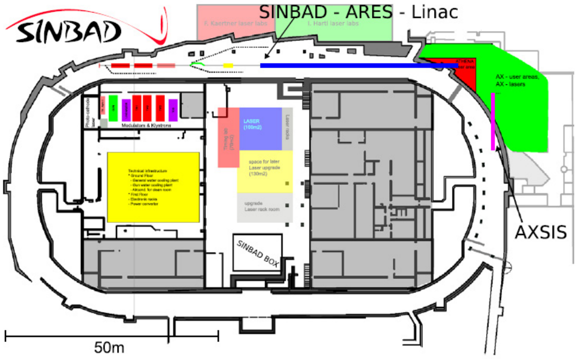

Figure 5: Layout of the SINBAD facility [1].

Beam Focusing and Injection in LWFA

One example of possible application of the ARES beam is the experiment about external injection into a laser plasma wake-field accelerator. The shortness of the ARES bunches (FWHM < 1fs), their foreseen excellent arrival time stability (RMS arrival time jitter < 10fs) and the e-bunch energy (100 MeV) make this linac especially suitable for high quality acceleration via LWFA [11]. A matching lattice after the magnetic compressor has been designed in order to focus down the beam to Courant-Snyder ß parameter of the order of the cm [12]. Preliminary 2D simulations were performed with the OSIRIS code [13] by considering parameters for the e-bunch corresponding to the ARES focused beam. The results show that it is possible to almost double the energy of the initial beam by accelerating it in a less than 2.5 cm long plasma cell, while keeping the relative energy spread of the beam smaller than 0.6%. Those simulations, using an almost hard-edge plasma model and including laser guiding, also show a substantial transverse emittance increase to 1.2 mm*mrad due to the expected transverse beam mismatch. This unwanted effect can be avoided by introducing a tailored density profile for the plasma [14].

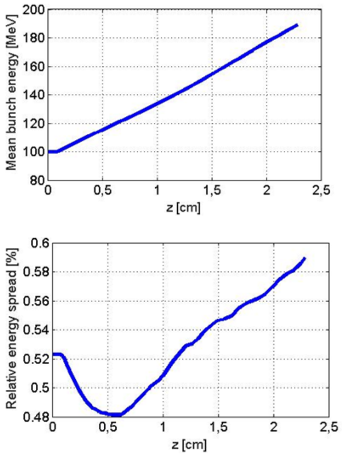

Figure 6: Evolution of the mean bunch energy and the relative energy spread of an electron beam having 0.7 pC charge injected in a plasma with density n=4.25*10^{16} cm^{-3}.

CONCLUSIONS

We have presented the current status of the design considerations for the ARES linac and their technical implementation. We have also provided some insights in its future applications. The start of the installation of ARES is foreseen to take place at the end of 2017 with the commissioning of the RF gun.

ACKNOWLEDGEMENTS

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