

# STATUS REPORT OF THE SINBAD-ARES RF PHOTOINJECTOR AND LINAC COMMISSIONING

E. Panofski\*, R. W. Assmann, F. Burkart, U. Dorda, K. Floettmann, M. Huening, B. Marchetti,  
D. Marx, F. Mayet, P.A. Walker, S. Yamin, DESY, Hamburg, Germany

## Abstract

The accelerator R&D facility SINBAD (Short innovative bunches and accelerators at DESY) will drive multiple independent experiments, including the acceleration of ultrashort electron bunches and the testing of advanced high-gradient acceleration concepts. The SINBAD-ARES (Accelerator Research Experiment at SINBAD) setup hosts a normal conducting RF photoinjector generating a low-charge electron beam, which is afterwards accelerated by an S-band linac section. The linac as well as a magnetic chicane will allow the production of ultrashort bunches with excellent arrival-time stability. The high brightness beam has then the potential to serve as a test beam for next-generation compact acceleration schemes. The setup of the SINBAD-ARES facility will proceed in stages. We report on the current status of the ARES RF gun commissioning and linac setup.

## INTRODUCTION

SINBAD [1] is a dedicated R&D facility in the former DORIS tunnel at DESY Hamburg. The goal is to test advanced acceleration techniques, such as Laser driven plasma Wake-Field Acceleration (LWFA), Dielectric Laser Acceleration (DLA) and THz-driven acceleration, in independent experiments. ARES [2] at SINBAD is a linear accelerator with a target energy of 100-155 MeV which is currently in the construction and commissioning phase. The facility will provide a low-charge, remarkably short-bunch electron probe beam with excellent arrival-time stability [3]. The design parameters of the electron beam are summarized in Table 1.

Table 1: Final Electron Parameters Planned at ARES

Bunch charge [pC]	0.5 - 30
Repetition rate [Hz]	10 - 50
Beam energy [MeV]	100 - 155
Norm. emittance (rms) [ $\mu\text{m rad}$ ]	0.1 - 1
Bunch length (rms) [fs]	0.2 - 10
Arrival time jitter [fs]	< 10

The following section provides an overview of the ARES layout and the current status of the accelerator installation as well as the RF gun conditioning.

## ARES LINAC LAYOUT AND CURRENT STATUS OF INSTALLATIONS

Figure 1 illustrates the planned layout of the ARES linac at SINBAD.

### Electron Source

Electron bunches will be generated in a normal-conducting 2.998 GHz RF photoinjector. The design is based on the 1.5 cell REGAE RF gun [4]. It is foreseen to implement metallic as well as semiconductor cathodes ( $\text{Cs}_2\text{Te}$ ) in the gun, depending on the desired bunch charge and bunch length. The photoelectric effect is then driven by a UV laser with 258 nm wavelength. The laser produces pulses with a pulse energy above 1 mJ and an rms beam size from 20  $\mu\text{m}$  to 0.2 mm in a flat-top shape. The Gaussian longitudinal laser pulse length can be varied between 180 fs and 10 ps (FWHM duration) [5].

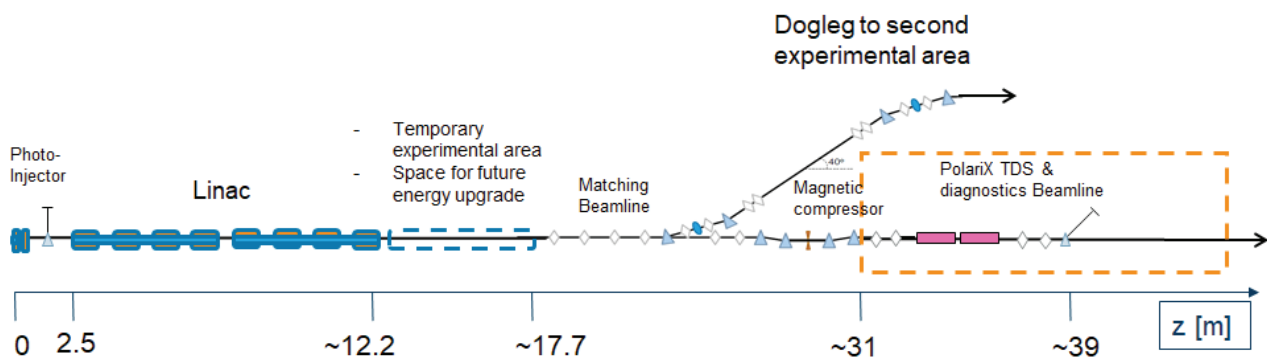


Figure 1: Layout of the ARES linac at SINBAD.

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\* [eva.panofski@desy.de](mailto:eva.panofski@desy.de)

A peak input power of 6 MW is required from the RF station which corresponds to an acceleration gradient of 117 MV/m. Therefore, the electron beam can be accelerated in the cavity to a final energy of more than 5 MeV. The electron gun will be equipped with a bucking coil around the full cavity cell and two solenoids that focus the beam in the transverse plane. Moreover, the solenoids will provide an improvement in the transverse beam quality by emittance compensation [6].

Several diagnostic tools in the RF-gun region will allow the characterization of the generated electron beam in the transverse and longitudinal plane. Several screens are installed for beam-size measurement [7]. TEM grids together with an additional screen downstream in the beamline enable single-shot emittance measurements [8]. The beam energy and energy spread can be characterized with a dipole spectrometer. Faraday Cups will be used to measure the beam charge as well as the dark current at different positions in the beam line. A further online charge monitoring is given by a dark current monitor [9].

Figure 2 presents the current status of the RF photoinjector installation. RF gun, support system, vacuum system, RF waveguides and precision water cooling of the RF gun have been completely installed. One solenoid is mounted after the gun coupler. The second solenoid and the bucking coil that will surround the gun cavity will be installed as an upgrade. The setup of the diagnostics is finished. The setup of the photocathode drive laser is displayed in Fig. 3. The laser system is ready for operation.

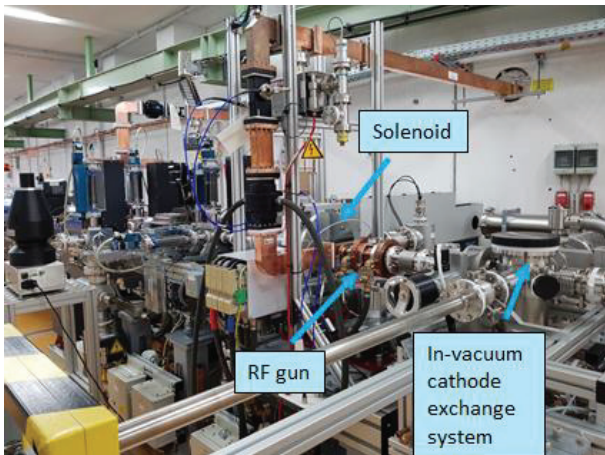


Figure 2: The installed ARES RF photoinjector in the SINBAD tunnel including the complete support structure.

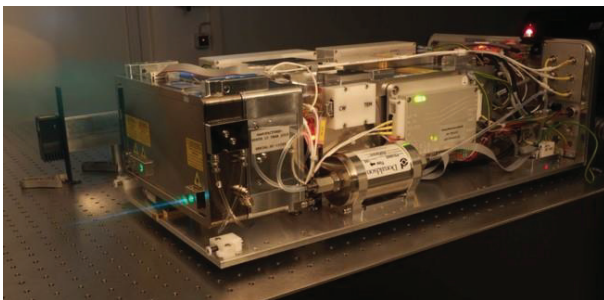


Figure 3: Photocathode drive laser in the laser room.

## ARES Linac

The ARES linac structure consists of two S-band RF cavities surrounded by four solenoids each [5]. The travelling-wave structures are powered by two independent RF-stations. The ARES linac can accelerate the electron beam to a maximum beam energy of 155 MeV in the on-crest mode. A reduced final energy of 100 MeV is assumed since the linac will not only accelerate the beam but also serve to chirp the bunch for bunch compression via velocity bunching and using a magnetic chicane.

The installation of both linac cavities together with the solenoids is finished. The mounting of the waveguides is presently ongoing and will be finalized in the next shutdown. The current setup is shown in Fig. 4. A third travelling wave structure has been ordered for a future energy upgrade of the beamline.

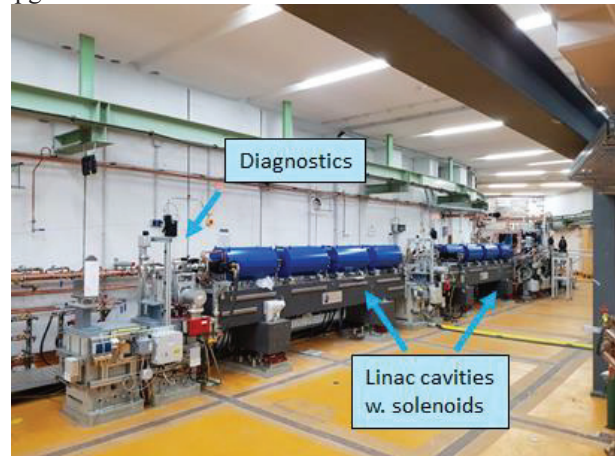


Figure 4: Current setup of the ARES linac.

## Experimental Area, Dogleg, Bunch Compressor

The space at the exit of the second travelling wave structure will temporarily host an experimental area (see Fig. 1). After commissioning of the ARES linac, the electron beam will be used to test the concept of DLA [10] in the context of the ACHIP project [11]. The lattice design for the first experimental area at the ARES linac is finished. The hardware is fully designed, including an UHV experimental chamber, a final focus triplet magnet system and beam instrumentation. The parts are currently in production and installation at the ARES linac is foreseen in autumn 2019. Designs for future upgrades are currently under investigation [12].

In a future upgrade a dogleg will be added to the ARES beamline that will be able to inject a compressed bunch to a second experimental area. The lattice design of the ARES linac dogleg is finished and the magnets are ordered. The installation of the beam line elements is foreseen for the first half of 2020.

Furthermore, a bunch compressor providing a variable  $R_{56}$  will be installed [13]. It is one of the key elements at ARES for generating femtosecond to attosecond bunches which will be optimized for external injection into a plasma cell. The design of the bunch compressor is finished.



## RF GUN COMMISSIONING

The conditioning of the RF gun started in February 2019. In order to keep the gun in resonance, an optimum temperature in the water cooling of 60°C was determined and set. Figure 5 shows the forward, reflected and the resulting probe RF pulse measured at the pick-ups in the gun cavity. A final probe peak-power of 6 MW is required. The gun conditioning is still ongoing.

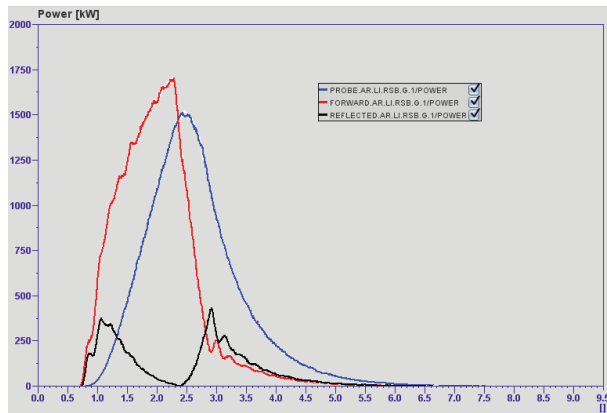


Figure 5: Forward (red), reflected (black) and RF probe pulse (blue) in the gun cavity. The RF pulse duration is 0.5  $\mu$ s. The modulator operates at a pulse width of 6  $\mu$ s and a charge voltage of 1200 V.

The optical system of the photocathode drive laser was aligned on the cathode in the RF gun. Therefore, the Cu cathode that is planned to be used for the RF gun commissioning was exchanged for a scintillating plug. Using an aperture with 1.12 mm diameter (FWHM) opening in the laser beamline, a 320  $\mu$ m spot size (FWHM) was measured on the scintillator. A smaller aperture of 200  $\mu$ m (FWHM) allows a reduction in the imaged laser beam size to 54  $\mu$ m diameter on the cathode. A picture of the first laser spot on the cathode was taken by a diagnostic camera [see Fig. 6].

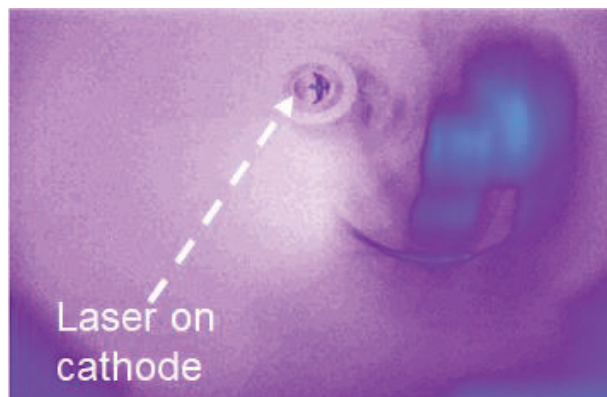


Figure 6: Laser beam on the scintillating photocathode after alignment.

A middle layer server [14] is successfully implemented to control all magnets of the ARES injector including the gun solenoid, two vertical and horizontal steerer pairs and a spectrometer dipole. The additional compensation coils for the earth's magnetic field are prepared. The diagnostic tools that will characterize the low-energy electron beam in the gun area are set up and operational. Panels have been

created and added to the control system to enable the movement of the screens, the grids and the Faraday Cups into the beam path. The screens are calibrated and the cameras are tested.

A first dark-current measurement which was also used to test the magnets and the diagnostics, was performed at an RF input power of about 1.6 MW. The dark current was focused on the first screen by the gun solenoid and one vertical steerer. A first small signal on the Faraday Cup induced by the two dark current spots displayed in Fig. 7 was observed.

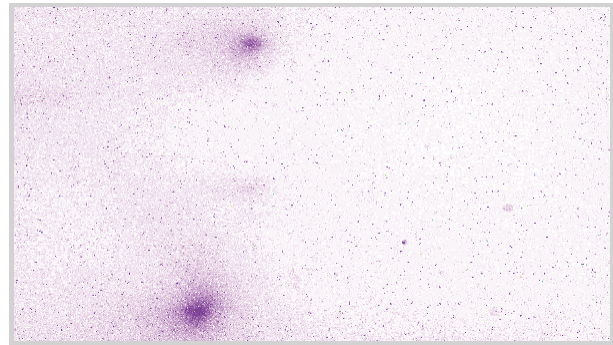


Figure 7: First dark current measurement during the gun conditioning at 1.6 MW forward RF power.

## CONCLUSION

This paper gives an overview of the layout of the ARES facility at SINBAD. We have summarized the current status of the installation and commissioning of the RF gun and the linac. The setup of the ARES gun is finished, RF power has been sent to the gun and the conditioning is ongoing. The installation of the ARES linac is advanced. The commissioning of the travelling-wave structures will start in the next months. The installation of the experimental area is foreseen in autumn this year.

## ACKNOWLEDGEMENT

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