ISBN: 978-3-95450-210-3 doi:10.18429/JACoW-FEL2019-THP085

STATUS OF Athos, THE SOFT X-RAY FEL LINE OF SwissFEL

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Abstract

The Athos line will cover the photon energy range from 250 to 1900 eV and will operate in parallel to the hard X-ray line Aramis of SwissFEL. The Athos FEL line starts with a fast kicker magnet followed by a dogleg transfer line, a small linac and 16 APPLE undulators. From there the photon beam passes through the photonics front end and the beamline optics before reaching the experimental stations Maloja and Furka. This contribution summarizes the two-bunch operation commissioning (two bunches in the same RF macropulse), which started in 2018, and the characterization of key components like the APPLE X undulator UE38. The Athos installation inside the tunnel is alternating with Aramis FEL user operation, and the first lasing is planned for winter 2019 / 2020.

Athos FEL LAYOUT

Athos [1] is the soft X-ray FEL line of SwissFEL (Fig. 1). Athos is currently under assembly and will deliver first FEL beam to the Maloja experimental station in 2020. This second branch of SwissFEL (Aramis being the hard X-ray FEL) starts at meter 270 (distance to the photocathode) with a resonant kicker [2,3]. This fast kicker separates the two bunches: one going to Aramis and the second one going to the Athos FEL line. The electron beamline portion between the resonant kicker (z=265 m) and the beam stopper (z= 383m) just upstream the 1st undulator is already installed and currently under beam commissioning. The undulator line consists of 16 APPLE X undulator [4] segments of 2 m length (Fig. 2). The inter-undulator section will have the usual quadrupole / BPM combination and also a small magnetic chicane made of permanent magnets. This chicane can be operated as an intra-undulator phase shifter or used to delay (5 fs max.) or shift transversally the bunch (250 µm max.). This chicane is the essential tool to provide a large variety of operation schemes [5]. In addition, a delay line chicane (500 fs max. delay) with four electro magnets splits the FEL line in two halves (Fig. 2). Each half can be tuned to a different K value to produce two different colors. The main diagnostic of the Athos FEL line will be an X band RF Transverse Deflecting Structure (PolariX –TDS [6, 7]) positioned downstream the last undulator to allow on line monitoring of the lasing portion of the electron bunch. The variable polarization of the deflecting force will allow measurements of the bunch length, energy and of the transverse slice emittances (vertical and horizontal). Downstream the beam dump, starts the X-ray front end which will include a gas monitor to measure the FEL pulse energy and position. The mirrors to deflect the FEL beam to the different end stations are located in a separate room outside the tunnel [8]. Athos will have three experimental stations, where two (Maloja and Furka) are already under construction. Maloja will start commissioning tests in 2020 and will focus on very short FEL pulses (few fs and below). After first SASE lasing, the next goal will be to operate Athos in the optical klystron regime using the inter-undulator chicane. This scheme will speed up the SASE process so that lasing with only half of the undulator line becomes possible. This will then allow the test of the two color mode of operation.

TWO BUNCH OPERATION

Two distinct lasers are illuminating the photocathode to produce two electron bunches separated by 28 ns. The repetition rate and also the machine protection system logic can be set independently for bunch 1 and bunch 2. This independence of both timing event systems is important for parallel operation of Aramis and Athos FEL lines. Both bunches are accelerated simultaneously up to 3.15 GeV. The radio-frequency macropulses of the injector S band and X band modulator have an extra step of about 28ns length in order to control the phase and amplitude of the bunch 2 independently of bunch 1.

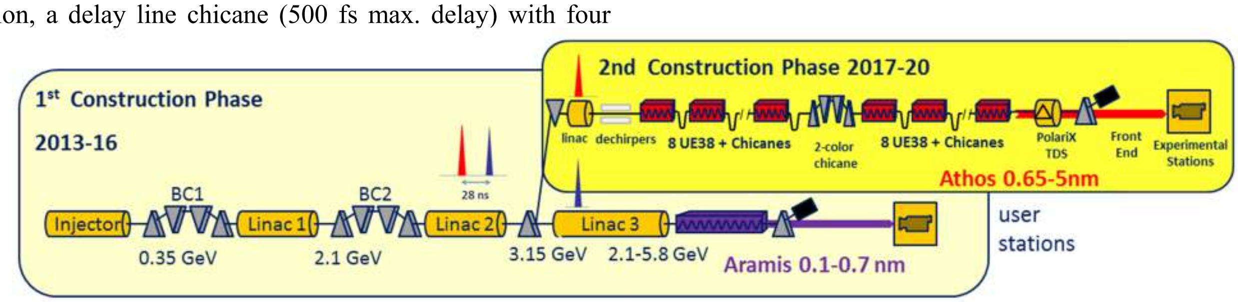

Figure 1: Layout of SwissFEL showing the extraction of second bunch at 3.15 GeV which is then transported along the Athos branch of SwissFEL.

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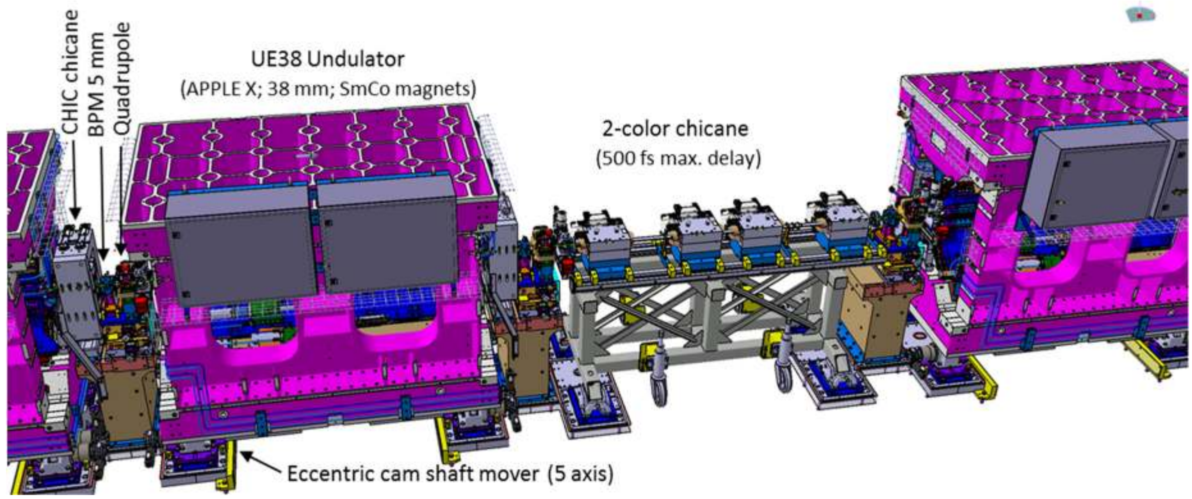

Figure 2: Layout of the Athos FEL line with the inter-undulator section (CHIC chicane, BPM, quadrupole), the APPLE X undulator and the two-color chicane.

This is important for fine tuning the compression of bunch 2. The C band Linac 1 and 2 are just delayed by 14 ns in order to have same acceleration for both bunches. The demonstration of two bunch transport from the RF gun to the extraction point has been achieved in 2018.The different feedback systems (orbit and energy) prepared for bunch 1 are also correcting bunch 2 as illustrated in Fig. 3.

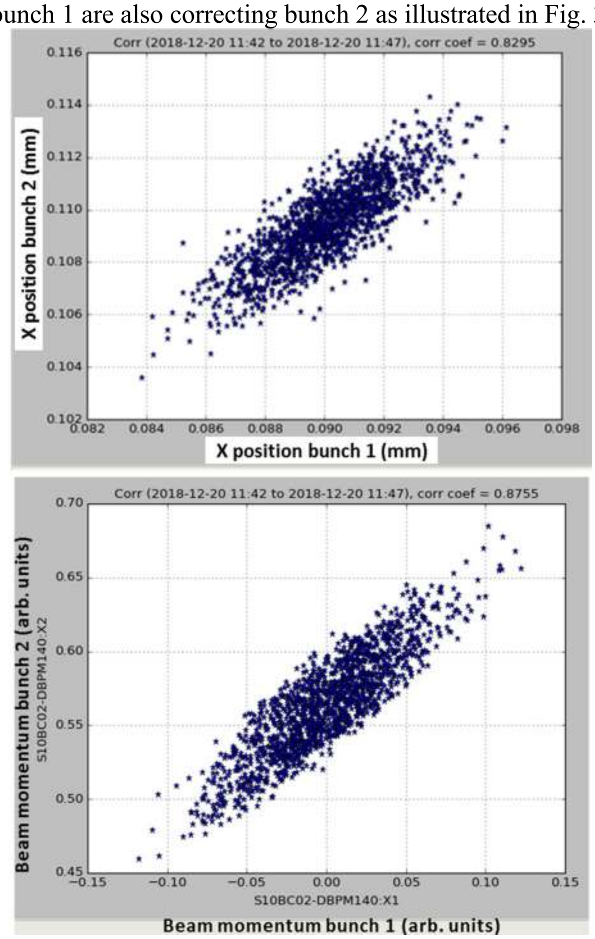

Figure 3: Correlation plot measurements of the BPM position of bunch 2 against bunch 1 (Top) and beam momentum of bunch 2 against bunch 1.

Transmission of the two bunches through the Aramis FEL line resulted in the lasing of both bunches simultaneously. This confirms that the quality of the second bunch was good enough for hard X-ray lasing. More important, the FEL pointing stability, 100 m downstream last undulator, was not affected by the fast kicker [3]. Keeping the beam emittance of second bunch when going through the dogleg section is however more difficult. This so called “dogleg” section requires very precise optic tuning in order to avoid deterioration of the emittance. An emittance of about 900 nm in both planes has been obtained (Fig. 4) during preliminary measurements. Magnet optic tuning should further reduce the emittance by about a factor two in order to support lasing of the second bunch in the Athos FEL line.

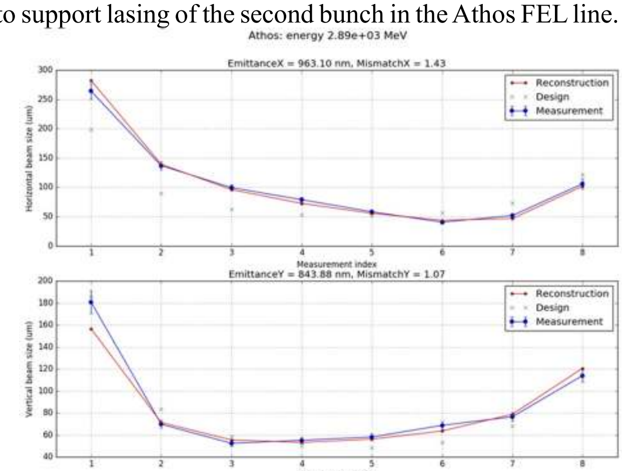

Figure 4: Projected emittance of second bunch measured downstream the dogleg at Athos undulator entrance (2.89 GeV, 200 pC).

APPLE X UNDULATOR

The 16 undulators segments of the Athos FEL lines are APPLE type undulators where the polarisation can be varied from linear to circular. One special characteristic of these APPLE “X” undulators is that the four magnets arrays can move radially and longitudinally (Fig. 5) [4].

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This allows, for example, to produce 45 degrees polarisation by inserting (closing) only the two arrays of the same diagonal. Another interesting feature is the possibility to generate transverse gradients. A transverse gradient together with a small yaw angle of the undulator will produce a linear tapering inside one undulator segment. The undulators are currently in serial production at a rate of one segment per month (Fig. 5).

Figure 5: Assembly of the APPLE X undulator at the factory site (Top) and Hall probe measurements (bottom left) and motorized shimming screwdriver (bottom right).

Thorough tests of the prototype undulator mechanics, of the hall probe measurements and shimming procedures have been recently completed. A rms phase error of 1.5° and an orbit envelope straightness within 1um was finally obtained (Figure 6). The mechanical position reproducibility (mechanical hysteresis) produces less than 10^{-4} dK/K variation.

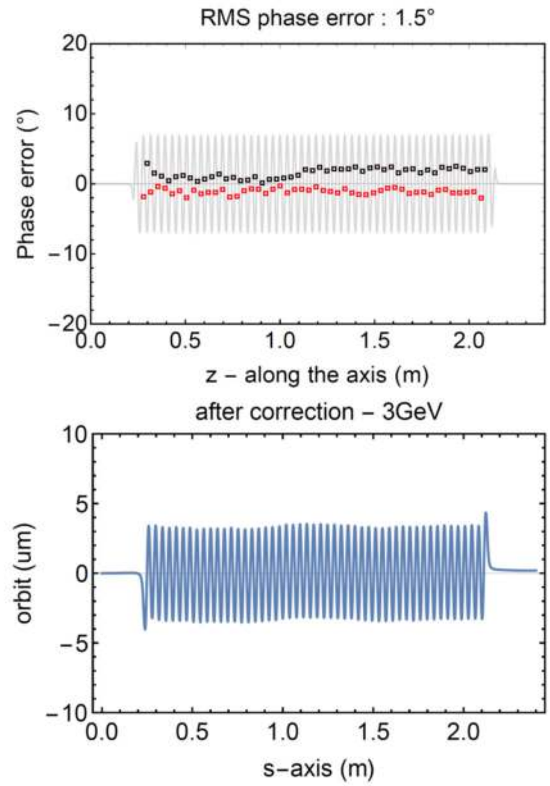

Figure 6: RMS Phase error (top) and horizontal trajectory (bottom) measured on the UE38 APPLE X prototype in linear horizontal (LH) polarisation.

SLICING AND EEHG

Recently the construction of a seeding / slicing option for the Athos FEL line was initiated. It consists in two external lasers, two modulators and two compression chicanes as depicted in Figure 7. The first stage of this seeding scheme (yellow highlighted) will allow the generation of ultra-short sub fs pulses synchronized to the external seeding laser. The second stage (orange highlighted) will offer the possibility to apply echo enable harmonic generation (EEHG) to produce high brightness beam up to 500 eV.

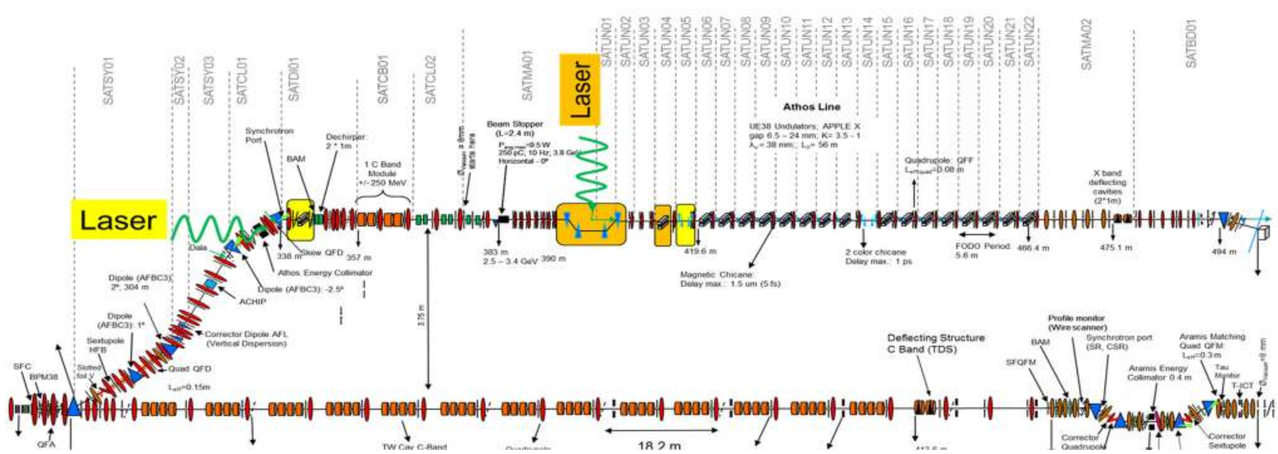

Figure 7: Layout of Athos FEL line showing the implementation of the seeding and EEHG components in yellow and orange respectively.

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