MICROBUNCHING OF THERMIONIC CATHODE RF GUN BEAMS IN THE ADVANCED PHOTON SOURCE S-BAND LINAC

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ABSTRACT

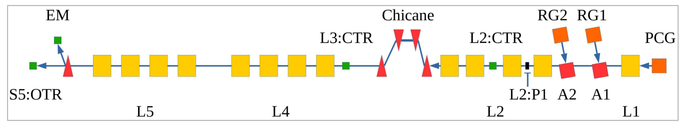
We report on measurements of beams from thermionic cathode (TC) rf guns in the Advanced Photon Source S-Band Linac. These measurements include the macropulse out of both new and existing TC guns as well as the observation of microbunching within the micropulses of these beams. A gun chopper limits the macropulse FWHM duration to the 10-ns range. Our objectives were to analyze the new TC gun and investigate microbunching within a TC-rf-gun-generated beam. Our diagnostics elucidated longitudinal beam structures from the ns to the fs time scales. Coherent transition radiation (CTR) interferometers responding to far-infrared wavelengths were employed after each compression stage to provide the autocorrelations of the sub-ps micropulse durations. The first compression stage is an alpha magnet and the second a chicane. A CCD camera was used to image the beam via optical transition radiation from an Al screen at the end of the linac and also employed to measure coherent optical transition radiation (COTR) in the visible range. The COTR diagnostic observations, implying microbunching on a fs time scale, are presented and compared with a longitudinal space-charge impedance model.

MOTIVATION

- The injection system of the Advanced Photon Source (APS) has relied on thermionic cathode (TC) rf guns as electron-beam sources since 2001 [1].
- This will continue to be the case for the APS Upgrade with the multi-bend achromatic magnet lattice installation in the 6-GeV storage ring currently in progress [2].
- We report the basic testing of the beams from new generation TC rf guns manufactured by RadiaBeam Technologies (RBT) [3] in terms of a macropulse composed of S-Band micropulses (2856 MHz).
- Comparison RBT gun with a TC rf gun purchased from AET Associates (AET) in 2001. AET guns have been the primary electron source for the APS since that time.
- Our interest was to measure the charge of each micropulse within the macropulse structure from the chopper-gated [4], TC-rf gun [5–7].
- The extraction of charge from the TC rf gun involves high-power rf applied to the cathode; thus, the extracted charge comes in a series of micropulses.
- With the macropulse temporal distribution, we can then determine the charge per micropulse.

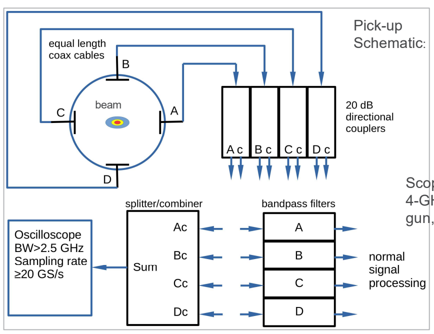
BACKGROUND

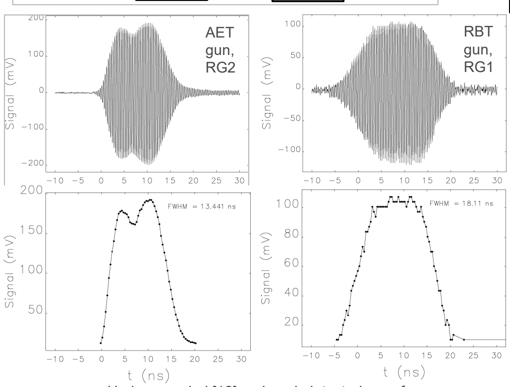
- An AET gun was employed for the bunch compression experiment discussed here
- Micropulse duration after the alpha magnet is sub-ps
- After further compression in the chicane, longitudinal-space-charge-induced (LSC) microbunching within the micropulses generates coherent optical transition radiation (COTR) when striking a downstream intercepting Al screen.
- COTR (visible wavelengths, fs temporal scale) was transported out of the tunnel to a CCD camera, and the images were recorded.
- We present a comparison of the observed COTR enhancements with the predictions of a LSC-impedance model.



Linac Schematic

EXPERIMENT S-BAND BPMS [9-11]

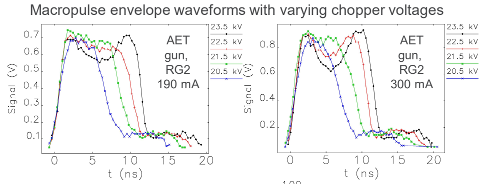




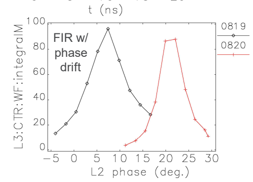
Under-sampled [12] and peak detected waveforms

MACROPULSE AND MICROPULSE

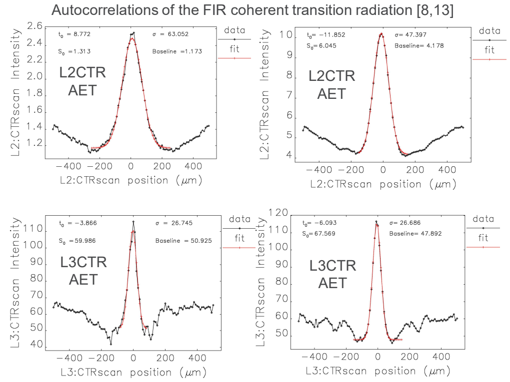
Macropulse envelope waveforms with varying chopper voltages



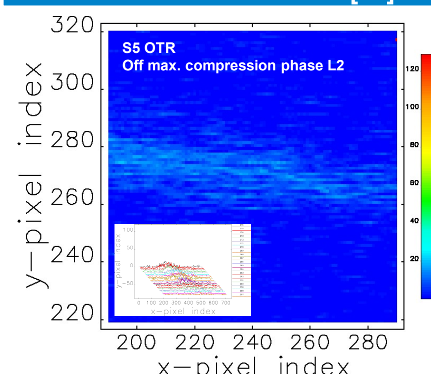
Scope display 4-GHz, RBT gun, RG1

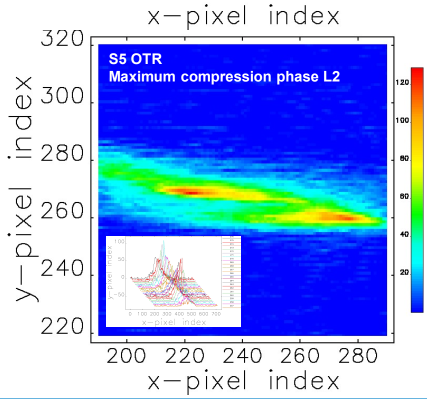


Autocorrelations of the FIR coherent transition radiation [8,13]



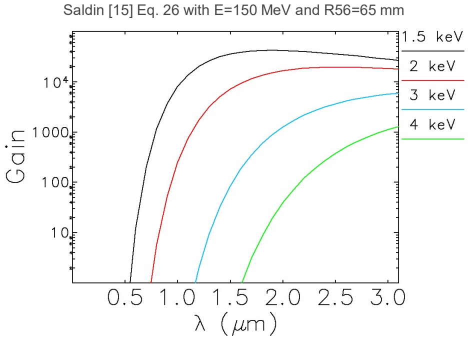
MICROBUNCHING [14]





ANALYSIS

Saldin [15] Eq. 26 with E=150 MeV and R56=65 mm



SUMMARY

- We described a method to measure the macropulse waveform of the APS TC rf guns, requiring an oscilloscope with bandwidth and sampling rate sufficient to monitor the fundamental frequency of the rf.
- In the present case, this requires a bandwidth>2.5 GHz and sampling rate>20 GS/s for 2856 MHz S-band rf.
- Measurement of the macropulse envelope allows for calibration of the microbunch charge and thereby calculation of peak currents after bunch compression.
- AET and RadiaBeam TC guns were tested and, accounting for differences in the chopper systems, behaved in a similar manner.
- We have inferred the presence of LSC-induced microbunching at visible wavelengths via the COTR mechanism from TC rf gun beams.
- After two stages of compression and with further acceleration to 375 MeV, an enhancement factor of 6.5 was observed in OTR near maximum compression.
- The enhanced emission is attributed to the generation of COTR from microbunching in the TC rf gun-generated micropulses.
- Analytical models indicate a slice energy spread of only a few keV is required for microbunching (COTR gain) at visible wavelengths where the CCD camera is sensitive. The importance of slice energy spread as it applies to a TC-rf gun beam is analogous to what was reported for PC gun [16] and LPWA [17] beams.
- Further investigations including spectral measurements of the microbunching phenomena are warranted[18,19].

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