# AN INTENSE ELECTRON LINAC FOR PULSED RADIOLYSIS RESEARCH AT SINAP

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*Abstract*

At the Shanghai Institute of Applied Physics (SINAP), efforts are underway to develop an intense pico-second electron beam pulse radiolysis facility for chemical studies. The main part of this new facility is a 10 MeV linac. Its target output is to generate electron pulses that can be changed between the single bunch with charge of >1nC in 10 ps and the multi-bunch with charge of about 10nC in 10 ns. The design, construction and preliminary commissioning of this linac are described in this paper.

## INTRODUCTION

Recent years have been an increasing interest in use of intense, short pulse electron beam for pulsed radiolysis research [1-3]. At the Shanghai Institute of Applied Physics (SINAP), a new intense pico-second electron beam pulse radiolysis facility is being developed for chemical studies. It consists of a 10MeV linac (i.e., ps-linac) for producing intense electron bunches with pulse length of <10ps or ~10ns, and experimental station. The requirements of the ps-linac are listed in table 1.

Table 1: Beam requirements

| | | |
|---|---|---|
| Beam energy | 4~15MeV | |
| Energy spread | <5% | |
| Normalized emittance(rms) | <100 mm·mrad | |
| Pulse duration | <10 ps | ~10ns |
| Charge per pulse | >1nC | ~10nC |

The design and construction of the ps-linac for radiolysis research have been under way at SINAP since 2002. Installation of the ps-linac has been successfully completed in 2003, and some preliminary tests have also been carried out. Fig.1 shows the view of the ps-linac.

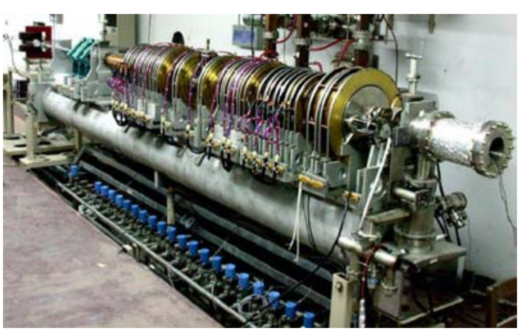

Figure 1: View of the ps-linac at SINAP

## MACHINE DESCRIPTION

Fig.1 shows the block diagram of the ps-linac, which mainly consists of an electron thermionic gun, a bunching system and one accelerating tube with focusing, vacuum, monitors and control systems. In this linac, we use main components, including the 100keV thermionic gun, 476MHz sub-harmonic buncher and 2856MHz fundamental buncher, already developed for the Shanghai IR free-electron laser (SFEL) at SINAP in 1990s [4]

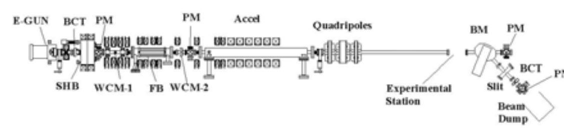


Figure 2: Schematic layout of the ps-linac

### *Electronic gun*

To produce high peak current of electron pulse, a ns classical Pierce gridded gun is used as electron source of the ps-linac. The gun cathode is a standard triode cathode with a 10mm diameter. The grid cut-off voltage is only ~60V (drive voltage of 200~250V), and allows a very short pulse of cathode emission. The distance between the cathode and the anode is ~30mm, and the anode hole's diameter is 8mm. The beam diameter is ~5mm at the exit of the anode with normalized emittance of ~10mm·mrad in the range of 1.0~2.0 A at 100keV.

According to the linac specification, the 100keV electron gun may produce a short single pulse of <1ns (FWHM), >1A or a long pulse of about 10ns (FW), ~1A at the repetition rate of 12.5Hz.

### *Electron bunching system*

The bunching system has been designed to capture more than 80% of the short single bunch beam (<1ns) produced by the gun within 10 degree (i.e., 10ps) of 2856MHz. This section consists of one sub-harmonic buncher (SHB) with frequency set at 476MHz (i.e., 6th sub-harmonic of 2856MHz) and a 2856MHz fundamental buncher (FB).

The SHB is a stainless steel re-entrant cavity operating at 476MHz. It is chosen so that the 1ns beam pulse of the gun extends roughly within ±90° phase spread at the SHB. Dynamic studies show that the optimum operating peak voltage over the SHB gap is 25~30kV, while the distance from the mid-plane of the SHB to the first cell of the FB is 60~70cm.

The FB is a tapered phase velocity travelling wave structure buncher with 12 cells in the 2π/3 mode at 2856MHz. The FB is designed to compress the bunch length from 60ps to <10ps, while accelerate the electrons to >2MeV. It is fed with 10MW RF power.

One lens behind the electron gun ensures the beam focusing at low energy. It is followed by a set of solenoids over the SHB and FB, to overcome the radial growth of beam emittance due to space charge and RF radial electric field in the SHB and FB.

### *Acceleration section*

The main accelerating section is a 1.3 m standard travelling wave 2π/3 mode tube, designed with a constant impedance for zero current. Beam dynamic simulations show that 9MW input RF power gives an energy of ~about 15 MeV at the exit of the linac.

### *RF system*

A homemade HK-1 type klystron has been chosen as the RF power source, and the modulator developed for the SFEL was modified to power the klystron with a macro-pulse length of ~3μs. RF tests up to 20MW output power has been successfully performed on a dummy load. 10MW output power of the klystron will be firstly fed to the FB, and then the residual power of about 9MW at exit of the FB will be delivered to the 1.3m accelerating tube.

### *Beam Diagnostics*

The output current and beam profile of the gun are measured by a ns-BCT and a profile monitor (PM) close to the gun, respectively. A wall current monitor (WCM) is located between the SHB and FB to observe the effects of the SHB. A WCM and a PM are installed behind the FB to measure the beam pulse and profile after the FB. At the exit of the linac, a beam charge monitor is used to determine the output charge per pulse, and two PMs are used to measure the beam profile. The last PM allows also measuring the emittance of the electron beam at exit of the linac. Moreover, an energy analysis station based on bending magnet is used to measure the beam energy and energy spread.

## PRELIMINARY COMMISSIONING RESULTS

Firstly, some preliminary tests of the electron gun have been performed to demonstrate the feasibility of a 1ns pulse and a 10 ns pulse. The beam parameters of both operation modes have been measured with the n-BCT (i.e., gun-BCT) and the profile monitor (PM) behind the gun. The 1ns pulse and 10ns pulse measurements have been encouraging (see in fig.3 and 4), and electron beam peak current of the gun was already higher than 1A in both operation modes.

To produce single bunch with pulse length <10 ps at the exit of the linac, operating peak voltage of SHB, RF phase between SHB and FB, and RF phase between FB and accelerating tube were optimised in the short single bunch mode. Fig.3 shows respectively the electron pulses at the exit of electron gun and at the end of linac with and without SHB (i.e., the SHB was turned on and switched off) in the short single bunch mode.

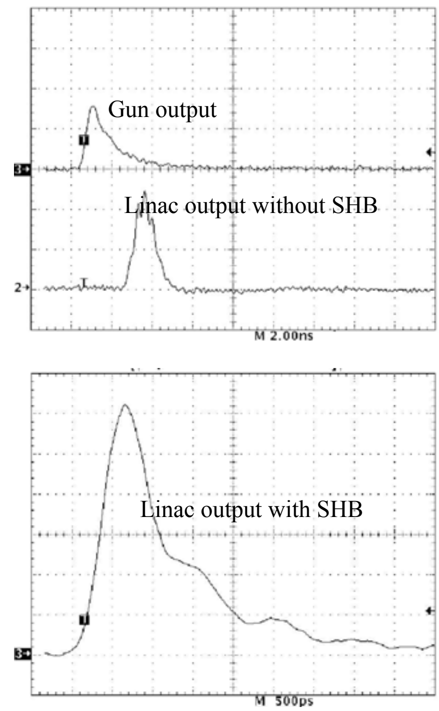


Figure 3: Short single electron pulse at the exit of gun and the end of linac with or without SHB

Fig.4 shows the electron pulses at the exit of electron gun and at the end of linac without SHB in the long pulse mode, and the FW of electron macropulse is about 10 ns.

Fig.3 and Fig.4 also indicate that the bandwidth of the monitor at the end of linac may be not high enough to clearly distinguish the S-band buckets.

Moreover, the electron beam energy at the end of linac has been also measured using the energy analysis station, and the maximum electron beam energy of the linac is about 15MeV in both operation modes, when the input RF power is about 10 MW.

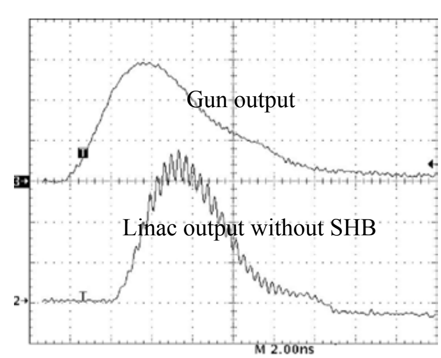


Figure 4: Long electron pulse at the exit of gun and the end of linac without SHB

## CONCLUSION

The SINAP ps-linac of the intense pico-second electron beam pulse radiolysis facility for chemical studies has been successfully installed and preliminarily commissioned. Measurements of the electron bunch length, emittance and energy spread of the ps-linac are being carried out.

## ACKNOWLEDGMENTS

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## REFERENCES

[1] T. Garvey, et al., Proceedings for EPAC2002, 254(2002)
[2] H. Iijima, et al., Proceedings for EPAC2002, 1771(2002)
[3] T. Kobayashi, et al., J. Nuclear Sciences and Tech. **39,** 6(2002)
[4] F.J. Yang, X.F. Zhao, et al., Nuclear Sciences and Tech. **3** (1992)