SSMB Workshop December 6-8, 2020
A couple of comments on SSMB for discussion – Alex Chao

Comment on the SSMB radiation

SSMB aims to provide a CW coherent radiation source for users who want high average power. In the high peak power regime, nothing can possibly beat the FELs. SSMB focuses on average power.

The key to the FEL lies in the microbunching. Attention is shifted from transverse dynamics of storage rings to longtiduinal dynamics of linacs,

Transverse	$\rightarrow$	Longitudinal,
Emittance	$\rightarrow$	Bunching factor.

SSMB follows its footsteps.

Coherence is a necessary requirement. Without the factor N^2, there is no high power. This is true for FEL and is true for SSMB. If the user wants incoherence, it cannot be done at the source. It has to be done after radiation is produced.

But for an FEL, the electron beam is too disrupted to be reused. This means FEL is a high peak power facility with low repetition rate. To gain average power, one naturally thinks of storage rings.

There is a spectrum of possibilities to use storage rings. One way is simply to insert an FEL into a ring. This "storage ring FEL" approach requires firing one shot every few radiation damping times. This is to use the storage ring as a linac. It produces high peak power but low average power, and not CW.

SSMB aims the other extreme. The beam is minimally perturbed by each passage of radiation and is not disrupted. The microbunched beam stays in a steady state in the storage ring.

Comment on why SSMB

Why SSMB?

- Clean radiation, THz to EUV.
- Frequency narrow-band, temporal CW, angular collimated
- High average power, EUV at 1 kW/insertion

Is it more difficult? — No, it only is different. Difficulty is comparable to high brightness synchrotron radiation facilities — neither is easy. Since there is no previous experience, we are starting a new series. Burden is upon us to do extra work to identify the best way to realize it:

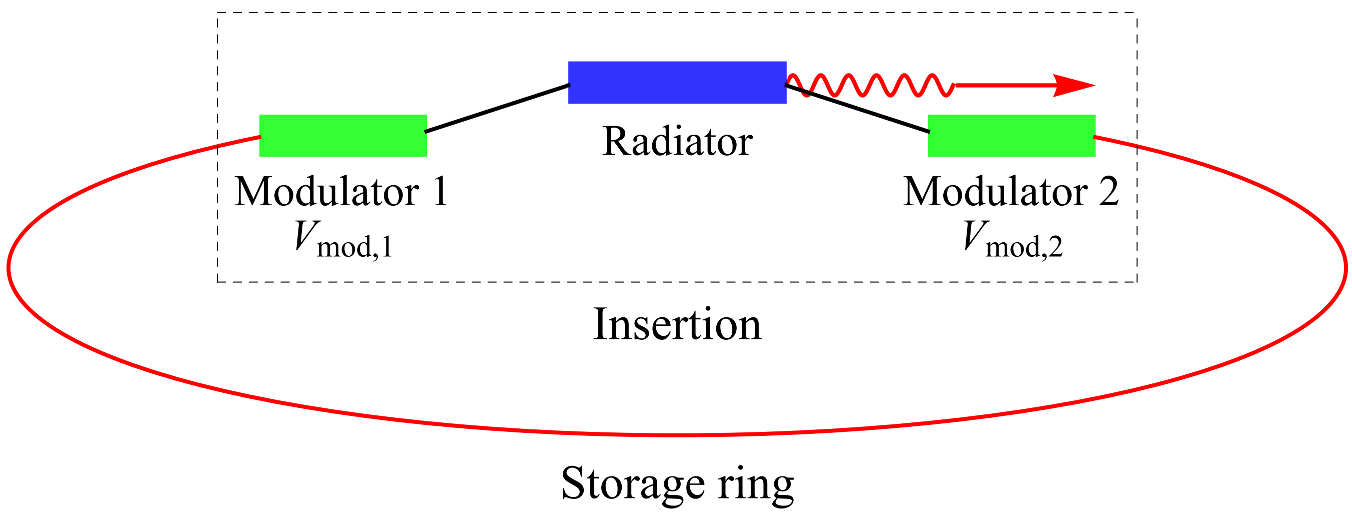
- Try a few design options, all in sufficient depth, and choose one.
- Proof of principle tests of key issues.

Comment on design options

SSMB is a general radiation source THz-IR-EUV. IR and THz are ready to go. EUV being the more diffucult. We take on the difficult case first.

The present goal of SSMB aims to provide a train of microbunches, each compressed to 3 nm, to go through a radiator for coherent 13.5 nm EUV.

It requires two parts, an insertion for the radiation and a storage ring.



- Insertion: Two laser modulators, sandwiching the radiator, with modulation voltages $V_{mod,1}$ and $V_{mod,2}$, to compress the microbunch length to 3 nm at the radiator. Bunching factor = 0.4.

  There are two options of modulators.

  1. "HGHG" option*: Compression done by the usual longitudinal HGHG mechanism, requiring modulation depth $\gg \sigma_\delta$. Need powerful laser.

  2. "ADM" option†: Compression done by vertical dispersion angle, requiring a small vertical emittance $\epsilon_y <$ (3 nm) $\times \sigma_\delta$, but laser power is moderate.

- Storage ring: There are two options for the ring.

  1. "Longitudinal strong focusing" option: $V_{mod,1} = V_{mod,2}$. The two modulators add, yielding a strong longitudinal focusing. Need small momentum compaction factor.

*L-H Yu, High Gain Harmonic Generation, 1991.

†C. Feng & Z.T. Zhao, Angular Dispersion-induced Microbunching, 2017.

2. "Reversible" option: $V_{mod,1} = -V_{mod,2}$. The two modulators cancel. The beam goes through the insertion with no net effect. It requires accurate cancelation of modulator voltages.

In total, there are 4 options. Progress is being made on three fronts, including lattice outline and parameter lists. All yet to be optimized.

	Long. strong focusing (microbunched in ring)	Reversible (not microbunched in ring)
HGHG modulator (longitudinal compression)	$\hat{P}_{laser} \sim 300$ MW (pulsed mode only) $\eta \sim 10^{-7}$ $I_{ave} \sim 1$A	
ADM modulator (vertical dispersion compression)	$\epsilon_y \sim 0.6$ pm $\eta \sim 4 \times 10^{-7}$ $I_{ave} \sim 1$A	$\epsilon_y \sim 0.6$ pm $(V_{mod,1}+V_{mod,2})_{noise} \lesssim 10^{-3}$ $I_{ave} \sim 10$ A

As we learn in depth each of these options, a final choice is optimized to be a hybrid design.

Comment on proof of principle tests

This is current highest priority. Two phases are in progress by a MLS/Tsinghua collaboration. MLS is the ideal small ring for the purpose.

(Jeorg Feikes's talk)

- PoP-I demonstrated the survival of microbunches for one turn in an isochronous ring setting.
- PoP-II: Keep the storage ring setting the same as PoP-I. Change the laser to 1000-shot. Having established PoP-I, this is expected to set the beam in a quasi-steady state. The goal is to study various multiturn effects of microbunched beams and compare with our expectations (i.e. it is not really "proof of principle").

In addition, depending on the design progress, a reversible insertion test may be needed to demonstrate the accurate cancellation of two synchronized laser modulators. This may or may not require a storage ring.

A real test is the systems test with an SSMB Prototype. All systems to be integrated in one prototype ring, including a user station.

Outlook (personal impression only, and excluding COVID): Proof of principle $\sim$0.5-1 year. Prototype conceptual design $\sim$1-2 years. Prototype ring $\sim$3-5 years. Collaboration with other similar projects worldwide.