Advanced Beam Cooling
LoI to Beam Physics and Accelerator Education

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Why beam cooling is important?

• Cooling techniques should be able to cool intense hadron beams at high energy, and they would counteract intrabeam scattering and control the emittance growth due to noise in the accelerator.
• They would also lower the transverse beam emittance in order for the beam to be focused in a tiny spot size at the interaction point.
• The electron-ion collider approved for construction at the Brookhaven National Laboratory needs strong hadron cooling to achieve the luminosity $10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$. This cooling should work with the beam intensities up to 2×10^{11} particles per bunch at the proton energy up to 275 GeV.
• There are two well-developed conventional cooling techniques for hadron and ion beams: the *stochastic cooling* and the *electron cooling*.
• These techniques found a broad application. However, they have their limitations. Stochastic cooling in the frequency range of several GHz is limited to relatively low-density beams. Electron cooling does not scale well to the proton energies above 10 GeV.

New ideas in cooling techniques

- In 1993-1994, Michailichenko, Zolotorev and Zholents proposed the *optical stochastic cooling* (OSC) which conceptually is an extension of the conventional stochastic colling to the range of optical frequencies.

- In 2008-2009 Litvinenko and Derbenev came up with an idea of the *coherent electron cooling*, in which the role of the pickup and modulator electrodes is played by an electron beam propagating with the same velocity and overlapping with the hadron beam.

- Further improvements of the CeC concept have been proposed under the name of the *micro-bunched electron cooling* (MBEC), and the so-called *plasma-cascade amplification* mechanism (PCA).

We need to advance the development of new cooling techniques

- While theoretical development over the last decade has firmly established the foundations for the new techniques, it needs to be continued. Computer codes are critical for the final evaluation of cooling-system performance.

Up to now, these novel cooling ideas have not been demonstrated experimentally. Currently several proof-of-principle experiments are being prepared.

- An OSC development program is underway at Fermilab's IOTA facility where OSC will be explored with 100-MeV electrons and first results are anticipated within CY20.
- An amplified-OSC development program is also underway at Cornell University's CESR storage ring with the expectation of tests with 1-GeV electrons within the next few years.
- A CeC-PCA cooling experiment is being developed at BNL. It is aimed at the demonstration of the cooling of ions with 26.5 GeV/nucleon in a 4-cell PCA system at RHIC, with the first results expected in CY21-22.

Challenges

• On the experimental side, the coherent cooling needs development of high-current electron beams that have internal low noise after acceleration to the energy exceeding 100 MeV and transporting the beam in the cooler channel. This requirement is critical for the success of the cooling.
• Another critical element, common to both optical and coherent cooling, is the precise, sub-micron control of the path lengths for the beams, which may require the development of new feedback systems.

Realization of these high-bandwidth cooling architectures will provide the accelerator community with a new portfolio of technologies for increasing the performance and flexibility of future accelerator facilities. Furthermore, the physics and engineering challenges solved in the process will undoubtedly support numerous other areas in accelerator science and technology, as well as many early-career scientists, postdocs and graduate-student researchers.