Report on the "Workshop on Beam Acceleration in Crystals and Nanostructures" (Fermilab, June 24-25, 2019)

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The concept of beam acceleration in solid-state plasma of crystals or nanostructures like CNTs (or alumna honeycomb holes) has the promise of ultra-high accelerating gradients *O*(1-10) TeV/m, continuous focusing and small emittances of, e.g., muon beams and, thus, may be of interest for future high energy physics colliders. The goal of the "Workshop on Beam Acceleration in Crystals and Nanostructures" which took place at Fermilab on June 24 and 25 , 2019, was to assess the progress of the concept over the past two decades and to discuss key issues toward proof-of-principle demonstrations and next steps in theory, modeling and experiment. The Workshop was endorsed by APS DPB, APS GPAP, ICUIL and ICFA ANA.

The Workshop had 40 participants from 6 countries, representing all relevant areas of research such as accelerators and beam physics, plasma physics, laser physics, and astrophysics. More than 20 presentations covered a broad range of topics relevant to acceleration in crystals and carbon nanotubes including:

1. overview of the past and present theoretical developments toward crystal acceleration, ultimate possibilities of the concept;

2. concepts and prospects of PeV colliders for HEP;

3. effective crystal wake drivers : beams, lasers, other;

4. beam dynamics in crystal acceleration;

5. instabilities in crystal acceleration (filamentation, etc.);

6. acceleration in nanostructures (CNTs, etc);

7. muon sources for crystal acceleration;

8. application of crystal accelerators (X-ray sources, etc.);

9. astrophysical evidence of wakefield acceleration processes;

10. steps toward "proof-of-principle" : 1 GeV gain over 1 mm, open theory questions, modeling and simulations

11. possible experiments at FACET-II, FAST, AWAKE, AWA, CEBAF, or elsewhere

There were many vivid discussions on these subjects. All the talks and summaries of the discussions are available at https://indico.fnal.gov/event/19478/

Several interesting proposals for further explorations or experimental tests were made by Sahel Hakimi et al (UCI, on how to drive wakes in CNTs by ultimate or existing Xray pulses from, e.g. the LCLS SASE FEL); by Aakash Sahai et al (U.Colorado, on production of detectable number of muons either in BELLA or FACET-II of FAST facilities and their subsequent acceleration); by Toshi Tajima et al (UCI, on demonstration of effective micromodulation of electron beams at FAST and FACET-II); by Vladimir Shiltsev et al (Fermilab, on experiments with micromodulated beams sent through CNTs at FAST (kA peak current type beams) and then at FACET-II (upto 300 kA bunches) and the CNT channeling demonstration); by Gennady Stupakov (SLAC, on possibility to use 1-nm-SASE-modulated electron bunches at the end of LCLS-I undulators to excite crystals and demonstrate acceleration); by Vladimir Shiltsev et al (FNAL, to study specific electron beam filamentation features in structured materials, crystals and CNTs, at FAST and FACET-II); by Johnathan Wheeler et al (Ecole Polytechnique, to use the APOLLO laser facility to demonstrate PW optical pulses/single cycle pulses via thin-film-compression technique); by Valery Lebedev et al (FNAL, to explore effectiveness of the wake excitation in crystals or CNTs by high-Z high energy ions, e.g. by 450 GeV ion beams from the CERN SPS available at the AWAKE facility, and observation of possible acceleration of externally injected electrons).

Formation of the research teams has began and followup presentations are being planned for the FACET-II Annual Science Workshop (Oct-Nov 2019).

We plan to summarize the results of the Workshop in the book of Proceedings which will be co-edited by Profs. Gerard Mourou (Ecole Polytech, 2018 Nobel Prize in Physics), Toshiki Tajima (UCI), Swapan Chattapdhyay (NIU) and Vladimir Shiltsev (Fermilab) and published by the World Scientific.