Responses to the questions

of the FACET-II PAC committee members immediately after the presentation of the

nano²WA proposal

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(on behalf of the nano²WA collaboration)

Ack: specific inputs from Prof. Katsouleas (UConn) & Dr. Resta-Lopez (Cockcroft)

Prof. I. Ben-Zvi

Would the target even survive the interaction ?

- In fact, this is the first question that our experiments will investigate single shot survival of the lattice has been simulated in GEANT4
- Study of ion-wake (*excited by sub-micron* ***e^- mode***) – **a key goal of our proposal**
- Study of long-term lattice survival **– a key goal of our proposal**
- **Ion-wake** – how ionic-lattice deforms, and ions gain energy due to the energy coupled from electron modes. The electron modes gain energy over ultrashort femtosecond time-scales.
- Our GEANT4 + ANSYS model shows that ionic lattice may survive – **single shot** ***strong bonds of nanostructures – can survive Giga-Pascal scale pressures***
- *CERN UA9 expt. – Si target survival - 10^{13} protons over ~10 micro-seconds*
- **Collisional Ionization** & **ionization due to emitted radiation** – estimated and being simulated
- **Ionization due to secondary particles** – estimated and being simulated

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effects of the structure being partly ionized (Ionization)?

- 100 kA FACET-II beam – *E_r > 1GV/m over 100nm radius* (proposed 10nm core radius nanostructures)
  300 kA FACET-II beam - *E_r > 1GV/m over 0.5-micron radius* (proposed 100nm core radius nanostructures)

- **Fowler-Nordheim tunneling** occurs across a solid surface – under high-field (field emission)
  typically studied for DC fields – *DO NOT know of any work on femtosecond Fowler-Nordheim tunneling*
- **1GV/m** is sufficient to pull out electrons (in DC limit) from the surface (*Fowler-Nordheim model*)
  RF breakdown occurs through Fowler-Nordheim field emission - much lesser fields (not well understood)

- Solid-state lattice is **already ionized**

- **"Free" e⁻** or **"Free" e⁻ gas** - already available and excitable (against the solid ionic-lattice)
- **Plasmonic mode** is based upon oscillation of "free" electrons in ionic lattice
  in direct & complete contrast with randomized ions in gaseous plasma where individual atoms are ionized

- **CRITICAL:**
  Nanostructures DO NOT simply provide a structured plasma – *entirely new dynamics of free e⁻ gas*

- In solids, high-fields DO NOT directly ionize individual atoms – already ionized (in the ionic-lattice)
  high-fields MAY further ionize the individual ions (atoms) of the lattice

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Is it dielectric wakefield in unionized regions (vs plasmonic)?

- Plasma / Plasmonic vs Dielectric – fundamentally different wakefield scaling
  Plasma wakefields dominate the effects on the beam (GV/m per pC)
  Dielectric wakefields are weaker (order of magnitude smaller effects compare to plasma)

- Dielectric modes - **dielectric constant** controls the interaction

- Nanostructure Plasmonic modes (nano²WA proposal) – **free e⁻ gas** controls the interaction
- *"Dielectric constant"* of **materials** with *free e⁻ gas* → INFINITY

- **Framework** of our model – resonant (matching bunch length) excitation of free **e⁻** gas (plasmonics)
  complete contrast with using dielectric constant (here tends to infinity) to engineer the field pattern

- *However, it may be critical to model and study the differences in the interaction:*
  when Fowler-Nordheim tunneling occurs (highly nonlinear radial surface oscillations)
  versus where such tunneling DOES NOT occur (weakly nonlinear radial surface oscillations)

- Further requirement to model and study:
  *when will the solid ionic lattice be **further ionized ?***
  *can plasmonic modes be excited in a **dielectric media ?***