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Program Managers Questions for LL14-AmBe Source

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Program Managers Questions for LL14-AmBe Source

Management/Execution

1. Who are the primary individuals working on this project and what are their roles? Are there key individuals outside your organization, students or subcontractors that assist your project?

   Andrea Schmidt is the PI on the project. Alex Povilus is the lead experimentalist. Steve Falabella and Harry McLean are experimentalists that assist as needed. Drew Higginson is an LSP modeler who is working on flashover calculations. Sheng Jiang is an LSP modeler who is working on helium DPF fluid-to-kinetic simulations.

   Outside our organization, Ahmed Badruzzaman, of Pacific Consultants and Engineers, is providing us with advice regarding oil well logging industry practices and needs. Mahadevan Krishnan of Alameda Applied Sciences Company is providing consultation regarding high-rep rate DPFs.

2. Is this project team engaged in similar work sponsored by DNDO, DTRA, DOE-NE or other NNSA offices? If so, please describe the technical area and application area.

   Our team is engaged in related work through NNSA (C4). In this work, we are modeling a large MegaJoule-class DPF located in Nevada to look for ways of increasing the yield and meeting requirements for their experiments. Additionally, we are engaged in similar work through LDRD and two other agencies.

3. Are there any publications or presentations that have been prepared from this effort? Please be sure to upload and properly account for all reports or publications generated by this project into webPMIS.

   We have presented this work at the American Physical Society Division of Plasma Physics meeting last year and we are presenting an update this year at the same meeting. Additionally, we plan to publish our measurements of helium and deuterium beams likely in FY16.

4. Please delineate planned project milestones and deliverables. Have all planned milestones and deliverables been met to date? What changes have been necessary and why? Do you anticipate any additional changes?

   We have met all of our deliverables, although we did not meet them in the original order that we proposed. Originally we were intending to measure the helium beam in order to come up with a predicted helium-beryllium yield. We would then insert a beryllium target only if the result of that looked promising

since we anticipated that use of a beryllium target would be large undertaking due to safety constraints.
Instead, we discovered that getting the safety approval to put beryllium in the chamber was relatively straight forward, while measuring the helium beams was rather difficult, for multiple reasons. Since we had such a large error bar on our helium beam measurements, and we had approval to put beryllium in the chamber, we opted to measure yield with beryllium first and then go back and characterize the beams. We are now characterizing the helium beam using a spectrometer instead of the original approach we tried using a time of flight Faraday cup diagnostic.

5. How do you track their progress and allow for efficient and cost-effective experimental planning?

   Every month we track the progress of the individual tasks based on what percentage of the task is done. We also track the budget and the resources available for the remaining tasks on a monthly basis. We have experimental planning meetings weekly or as needed, and we have modeling meetings weekly.

Scientific/Technical Soundness

1. What are the current project goals?

   Our remaining project goal for the year is a measurement of the ion energy spectrum and comparison to simulations. We have already built the spectrometer for this measurement and have obtained preliminary results. Modifications to our scintillator and additional experimental time is needed to fully characterize the ion beams. We expect to have this done by the end of the FY.

   Additional gains on the neutron yield this year (currently the highest yield is 2.5×10^{3} per shot) would be ideal. Our next steps for increasing the yield is to pre-ionize the plasma and to lessen the sputter from the stainless steel anode onto the beryllium target. There are several different ways to pre-ionize and we will likely only have time to try one of them before the end of the FY. We plan to try pre-ionizing using a plasma flashover ion source. To minimize the sputter, we plan to re-design the anode so that the heat load gets more evenly distributed.

2. Is the technical program plan reasonable and likely to achieve the project objectives?

   We are likely to achieve our project objectives for the feasibility study this FY. The main objective is to characterize the ion beam. An increase in neutron yield would be even better, though achieving a particular yield was not a deliverable for the feasibility study.

3. Please describe the progress to date and indicate how well it meets the agreed to milestone and deliverable schedules.

The agreed upon milestones were (1) measurement of the helium beam in February 2015 and (2) report on feasibility in June 2015. We got a rather late start on this project since existing LLNL personnel were fully subscribed when the project came in, and it took us a while to hire people with the expertise needed for this project. Because of this situation, NA-22 allowed us to extend our report on feasibility to the end of the FY.

(1) The measurement of the helium beam will be late, but will still be completed within the time frame of the feasibility study. Our new team members did not start until April/May, which is part of the reason that we did not have a beam measurement by February. The other reason is that we encountered unexpected difficulties trying to get the helium plasma to pinch, so there was no beam to measure initially.
(2) So far we have demonstrated that this concept is feasible in that we can generate He-Be neutrons. We expect the report on feasibility to be done on time. However, so far we have only achieved required yields in the simulations. We believe we have a path forward to continue to improve experimental yields, though it is unlikely we will meet the yield requirement (1×10^7) this fiscal year.

4. What additional unresolved technical issues can you anticipate that may potentially cause difficulties? The generation of He/Be neutrons was more difficult than anticipated. Why is that? Was it a modeling issue or a hardware issue? What breakthrough led to solving the problem?

The main difficulty that we encountered and that we are still challenged by today is the different behavior of helium gas, relative to deuterium (which is what we are accustomed to). Even though we are now consistently pinching in helium, we find that the timing of the pinch indicates that only half of the helium gas is getting ionized and swept up. This may be causing restrike issues.

The generation (and detection) of He/Be neutrons was certainly more difficult than anticipated. This was partially because we were not pinching consistently in helium at first, typically only on 10% of shots. This was a hardware issue. Both conditioning and a new anode shape helped with this problem. We now pinch on 95% of helium shots. We expect performance to improve further with pre-ionization.

An additional initial barrier which may still be keeping our yield low is sputter from the anode onto the beryllium target. This coats the target with the anode material (copper, eventually changed to tungsten), reducing the He-Be yield by slowing the helium before it reaches the target. We will be working on reducing/eliminating the sputter either through re-design of the anode or by making the anode out of beryllium so that the sputter is also beryllium.

5. What criteria were used to choose the He/Be reaction? Are you considering using something other than the He/Be reaction?

We chose the He/Be reaction in order to duplicate (or nearly duplicate) the AmBe spectrum. We were told that the well logging industry has decades of calibrated data using the AmBe spectrum and that to produce something similar in an accelerator format would be a big break-through.

Now that we've talked to representatives at several companies, we realize that not everyone in that industry wants an AmBe-like replacement. Some are of the opinion that a DT neutron tube will work fine. Others would like a DD tube with higher yield due to the higher sensitivity of 2.45 MeV neutrons to porosity. We are looking for additional feedback from the review team.

If we were to consider another reaction in the future, it would be DD. This is because of the high cross-sections and the lack of an existing DD tool that meets yield requirements. In addition to the sensitivity of the lower energy neutrons to porosity, the DD reaction also has the advantage that it eliminates the safety and regulatory concerns associated with tritium. We believe the DPF is a viable path to reaching required DD yields. In fact, we are building next FY a very small (100 J) DPF that will be close in yield to the requirements already.

6. What flux has been achieved using the different reactions?

For He-Be, the maximum flux achieved so far is 2.5×10^3 per shot. In deuterium, the maximum yield achieved so far is 5×10^7 per shot. It took us almost 3 years of R&D to achieve this flux in deuterium, and we suspect it may take another year to achieve yields this high in He-Be.

7. Is He a good choice at this time? Would working with a different gas be instructive "on the way" to He?

Most of the barriers to achieving higher yield in He-Be are likely due to ionization issues with helium. Thus, in order to solve these problems, we believe we must continue to work in helium and learn how to control/improve the flashover and ionization.

8. A recent report states that if the pulse rate is 5Hz, then the neutron flux goal could be met. Is this pulse rate achievable? If not, then what is needed to achieve it?

Yes, a pulse rate of 1-100 Hz has been demonstrated on DPFs this size, so this is something that we already know is possible. It will likely require active cooling, something we plan to implement in year 3 of our proposed follow-on work. We chose not to do this activity sooner for a couple of reasons: first, we propose to bring down the power requirements in year 2, and it makes more sense to design an active cooling system *after* the power requirements have been reduced. Second, the repetitive pulsing is the least risky part of the proposed 3-year project. Thus it makes sense to spend money upfront dealing with the potential "show stoppers" instead of a modification that we know we can make work.

9. What are the simplifying assumptions made in the model? In general, what differences between experimental results and the model are expected based on the way the model is built? How does this limit the value of the model?

The biggest assumption in the model is that the flashover of the insulator is clean and creates a desirable “thin” plasma sheath. Detailed modeling of the sheath formation is a type of modeling that is only now in development. Only in the last year has any group published the results of flashover along the insulator surface of a DPF. We are equipped to do this modeling, and have started our first efforts. However, we expect the learning curve to be steep. Hopefully we will understand the sheath formation process better by the end of the feasibility study, though we may or may not have time to implement a better insulator/cathode combination this FY. The insulator flashover modeling would continue if the follow-on project were funded, and would drive subsequent improvements to the insulator length and cathode shape.

10. How are you using the model to drive the experiments in a clear and rational manner?

The various parameters which we can control in the experiment generally fall into 3 categories:

(1) Parameters which are easier to test experimentally than they are to model (pressure/voltage scans)
(2) Parameters which are easier to model than to test experimentally (anode shape/length, capacitive driver parameters)
(3) Parameters which are not yet being captured in the model (plasma sheath flashover across the insulator, impurities, radiative losses)

We use the model to drive experiments by primarily scanning over parameter space for those in category (2), while also continuing to improve the model so that it incorporates more effects from category (3). While scanning through parameters in (2), we start with the parameters that are easiest to change experimentally. For example, one change we made this year that was driven by the modeling was the anode shape. If follow-on work is funded, we would begin to look at capacitive driver optimization also, since that will likely be needed in order to get the yield up to required levels. We typically don’t model parameter scans from category (1), although we do occasionally for benchmarking purposes.

In addition to performing parameters scans with the model, we also use it to understand the DPF and its physical acceleration mechanisms, something that had been theorized about until we had the fidelity to model it kinetically. We have used our new understanding of the DPF to find ways to increase the total beam accelerated and the energy of that beam.

11. Is the model validated for the current application? If not, then is the model validated for a related system?

The model has been benchmarked against neutron yield on the deuterium version of the current system. We will need the helium ion beam measurements to benchmark the model for the current application, and we expect to have that by the end of the feasibility study.

12. Is there specific data that are needed to improve or validate the model? Are the fundamental physics mechanisms understood? If not, then what data are needed?

We now understand the physical mechanisms that accelerate the beam pretty well. An ion beam measurement would be a very good way to benchmark the model in both helium and deuterium (and far more constraining than a neutron yield benchmark).

13. Are there any tangential technologies/techniques that could be developed to aid the progress of this work?

At the moment, one of the limitations is detection of the MeV-energy ion beams from the pinch for diagnostic purposes. Calibration of available scintillators or phosphors at this energy scale would be a necessary to evaluate absolute ion numbers. Currently, these calibrations either do not exist or are not well documented.

Additionally, the final product could benefit from advanced compact low-inductance capacitor technology, although existing capacitor technology would be sufficient to meet size requirements.

Potential User Impact

1. What end user agencies are interested in the capabilities of the technology and procedures being developed in this effort? Are you incorporating the input of potential users to guide your research plan?

   Ahmed has many contacts in the well-logging industry, and he has informally surveyed them regarding the DPF technology. He has found great interest among some of his colleagues and less interest among others. Both Andrea and Ahmed are involved in an AmBe scoping study that will better define the requirements of end users through a formal survey. We are hopeful that the independent review will also provide us with some feedback regarding the level of interest in the final product.

2. What are the competing approaches to solve the proposed applications issues? How is your approach better?

   The main different approaches to date are (1) AmBe radiological source, (2) DT neutron source, and (3) DD neutron source. Approach 1 is what we are trying to replace for safety and security reasons.

   Approach 2 has been tried already and used successfully in some scenarios. Opinions are mixed as to the success of approach 2. Some down-sides of approach 2 are (A) the 14 MeV neutrons are less sensitive to porosity than the lower energy AmBe neutrons and (B) the lack of thermal neutrons from the DT tool makes the measurement highly sensitive to standoff distance, which can cause the measurement to be inaccurate in areas of sand, leading to an interpretation issue.

Approach 3 has also been tried, but not successfully so far. The 2.45 MeV neutrons from DD fusion are more suitable for porosity measurements than the DT neutrons, but due to the lower cross section, no DD tool with high enough flux has been developed yet. We believe that the DPF could achieve the needed fluxes for a DD tool.

3. What specific product could be developed and passed on to an end user?

   We could envision either a He-Be or a deuterium DPF being passed along to an end user, after it was compacted and tested for robustness to vibrations and temperature swings. AASC could be contracted to make the first units for field testing after the prototype is shown to work.