Progress Report for Grant DTRA1-11-1-0036

for the period May 19th, 2011 – Sept. 1st, 2012

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1. Cover Sheet:

This is the second Progress Report on Grant DTRA1-11-1-0036 as per Exhibit B, Par. 22: "Technical Reporting Requirements" of the corresponding Contract. The original PI of the project was Dr. Marc Mitchell, Res. Asst. Professor at the Idaho Accelerator Center, Idaho State University. The current PI of the project is Dr. Vesselin I. Dimitrov, Res. Assoc. Professor at the Idaho Accelerator Center, Idaho State University.

2. Objectives:

The overall objective of the funded work is to design, build and test a system to non-destructively convert the Idaho State Induction System (ISIS) induction cell driver (ICD) to a low impedance pulse power driver for plasma radiation sources (PRS). The goal is to design the system in such a way as to be reversible and with minimal time to switch between the plasma radiation source mode and the normal operation mode of ISIS. Once built, another objective, a further objective is to continue developing high-energy density PRS for studying many of the DTRA core objectives, in particular – provide a plasma radiation source test platform for simulating nuclear weapons effects and its relevant science.

The objectives of the individual tasks for the first and second year of the project are, as originally scheduled, as follows:

Task 1: Design and construction of the PRS chamber (Year 1)

1.1) Design and simulation of the PRS chamber (Sept. 2011);
1.2) Fabrication of the PRS chamber (November 2011);
1.3) Connection of the fabricated chamber to the ICD (January 2012)

Task 2: Testing and refinement of PRS chamber (Year 1)

Testing the electrical characteristics of the PRS driver and completing any refinements that are found necessary. These could include, but are not limited to, modifications in insulating rings, attachments of transmission cables and modifications of the reflected pulse suppressor (June 2012).

Task 3: Preliminary X-pinch tests (Year 2)

Identification of a suitable range of material, mass (wire diameter) and geometry to match the new PRS driver (September 2012).

Task 4: Assembly of the radiation diagnostics (Year 2)

This should occur in parallel with Task 3. All necessary diagnostics should be in place by January 2013.

Task 5: Optimization of radiation parameters for imaging (Year 2)

Identification of the optimal parameters of a X-pinch loads for low (<1keV), intermediate (1-8keV) and high (8-20keV) energy bands. Characterization a great number of X-pinch materials, sizes and geometries for future specific imaging needs (June 2012).

There have been no revisions or modifications of the objectives stated in the original SOW. The project's schedule, however, needs revision as explained below.

3. Status of Effort:

The project began on May 19, 2011 and is currently in its second year's 4th month. Three months later the original PI, Dr. M. Mitchell, and the original Co-PI Dr. K. Chandler (his spouse) moved to another university. Because of this, no work was conducted during the first 9 months of the duration of the project. A new PI, Dr. Vesselin Dimitrov, was approved on February 7th 2012, who immediately, and together with an undergraduate student Caitlin Graff, started working on the design of an impedance transformer. The impedance transformer is the most important part of the PRS chamber and serves to combine the five 300kV outputs of the ISIS' induction cell driver (11Ohm each) into one low impedance (<1Ohm), 40-80kV output to be fed into the PRS chamber proper. The design criteria were chosen to be simplicity, low cost and high reliability. We came up with a water-filled strip-line impedance transformer/combiner without switching. Final optimization of the design of the transformer is underway.

In the late June 2012, the ISU graduate student Roman Shapovalov joined the project's team. He is currently learning to use the Remcom's FDTD electromagnetic simulation software, and when he comes up to speed the work on this project will be his principal task.

Overall, we judge that in order to catch up and successfully accomplish the project's tasks, a no-cost extension of the period of performance from 6 to 12 months will be necessary.

4. Accomplishments/ New Findings:

During the last seven months work on Task 1 of the SOW has been conducted. Analysis of the ISIS' induction cell driver showed that the most suitable spot for tapping its output pulse is at the end of the water-filled pulse forming lines (PFLs) before the oil-filled connectors to the high-voltage cables (Fig. 1).

Fig.1 ISIS induction cell driver. The future position of the impedance transformer is indicated by the red arrow.

Since the pulse at that location is a nice 300kV flattop with ~75ns duration, it was decided to use it directly without self-breaking switches. The X-pinch driver needs to output relatively low voltage (40-80kV) at very low impedance such that high wire current could be achieved. Thus, a transformer/combiner is necessary to combine the five PFL outputs and transform down both their voltage and their impedance by a factor of ~5. A finite element, time domain electromagnetic simulation code FDTD from Remcom was used to design and simulate a strip-line, water-filled transformer/combiner with the above specifications (Fig.2). Strip-lines were chosen for their easiness to make. The ISIS cell driver PFLs are water filled themselves, so a water-filled transformer is most naturally coupled to them with minimal additional components. Furthermore, de-ionized water suggests itself as an insulator because of its large dielectric constant (~81). The necessity of low output impedance of the transformer calls for using an output PFL whose size can only be kept reasonable with the use of high dielectric constant insulator.

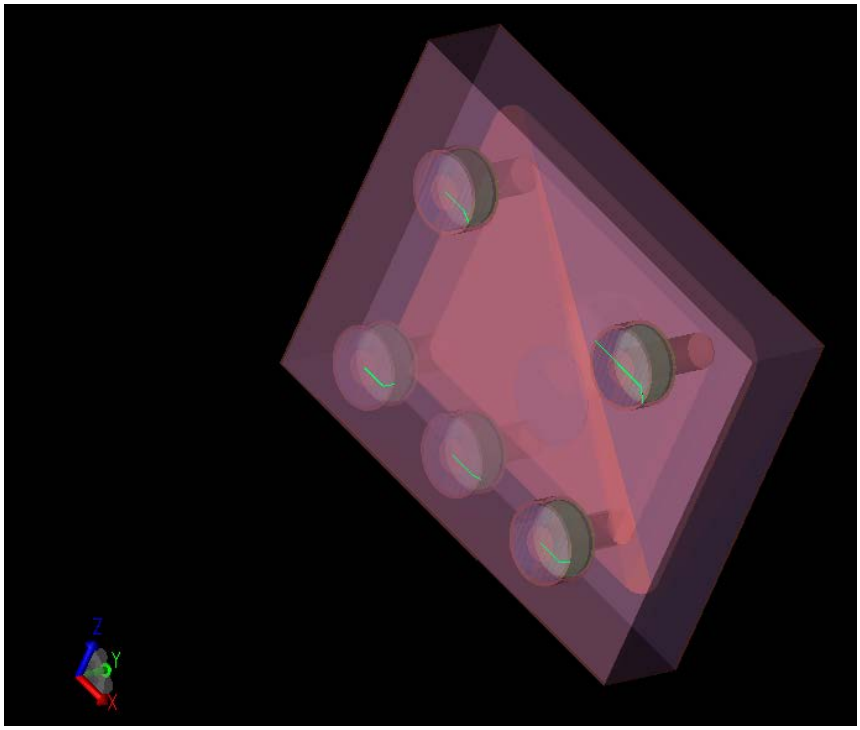

Fig.2 Impedance transformer/combiner model. Visible are the five PFL high impedance, high voltage inputs.

With the nominal ISIS cell driver's 300kV, the simulated output of the transformer is shown on Fig.3. The post-pulse ringing is caused by the mismatch of the output PFL's impedance and the load. The finalization of the transformer's design will be accomplished after the effect of misfire of one or more PFL is examined and some additional optimizations are performed, which, even though straightforward, are very time-consuming. A particular attention is being paid to the consequences (possible destructive for the ISIS cell driver) of reflected pulses due to breakdowns or other abnormal events in the impedance transformer.

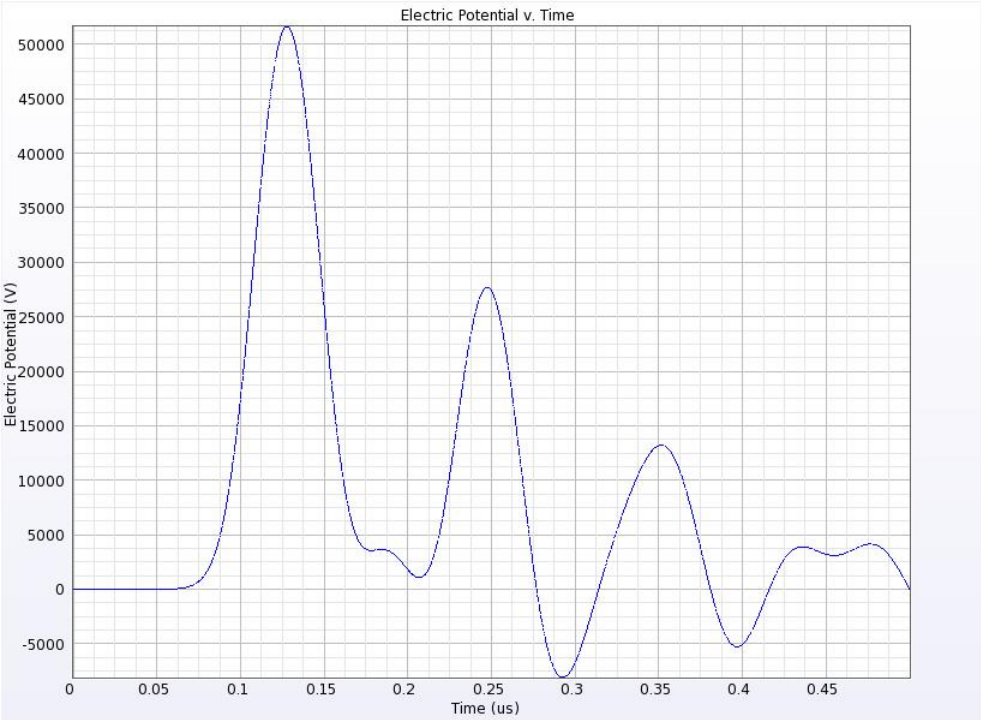

Fig.3 Simulated output voltage of the impedance transformer/combiner model for a standard ISIS cell driver input.

Overall:

The project's research has suffered a serious delay due to Dr. Mitchell's move to another university and the subsequent change of the project's PI. Effort is underway to catch up with the planned work. A 6 to 12 month no-cost extension of the project's period of performance may be necessary in order to successfully accomplish all project's tasks. In order to facilitate keeping track of the effort's progress, the PI will be turning in quarterly progress reports until advised otherwise.

5. Personnel Supported:

This is a list of people associated with and partially supported by the research effort during the period Sept. 2011 – Sept. 2012:

Dr. Vesselin I. Dimitrov, Res. Assoc. Professor, IAC, ISU (PI)

Roman Shapovalov, Grad. Student, Physics, ISU

Caitlin Graff, Undergrad. Student, ISU

6. Publications:

Nothing to report.

7. Interactions/Transitions:

V. Dimitrov attended the 2012 International Power Modulator and High Voltage Conference, which has taken place from June 3rd to June 7th 2012 in San Diego, CA. He had a number of useful discussions with pulse power experts from the Sandia National Laboratory concerning the impedance transformer for the PRS.
R. Shapovalov attended the Remcom's complimentary workshop on the FDTD code, which took place from August 20 to August 24 in San Jose, CA.

8. New Discoveries, Inventions, or Patent Disclosures:

Nothing to report.

9. Honors/Awards:

Nothing to report.

10. Courses Taught:

Nothing to report.