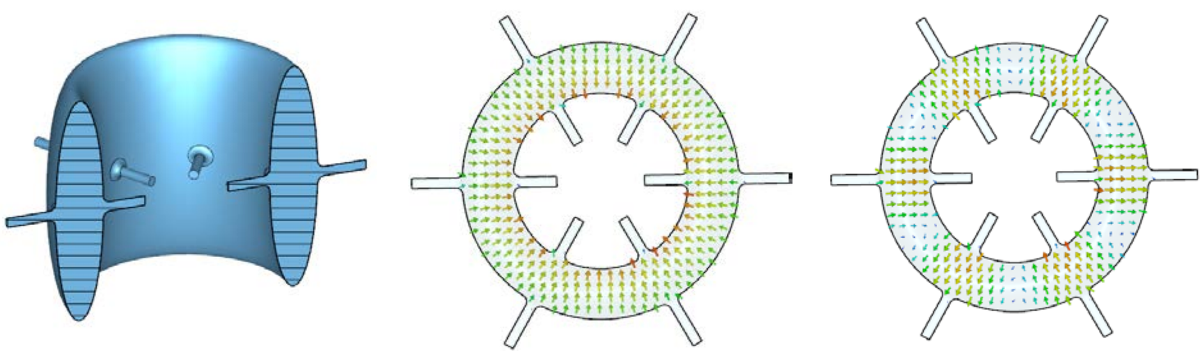
Radial RF Injectors for Improved Waste Stream Processing Progress Report
1Q FY18

Task 0 – Program Management
We are working to transfer funding to AFRL. As of the end of 1Q FY18, the funding transfer document package is at LAFO.

Task 1 – Beam Physics Design
We developed two preliminary concept models for a radial RF injector, one based on a single accelerating gap and one based on a dual-gap, coupled-cavity configuration. Tuning the coupled-cavity configuration proved possible. However, the field balance appears sensitive to small changes in the geometry, similar in principle to behavior exhibited by 1.5-cell photoinjectors. We therefore focused on single-gap geometries going forward, translating the basic design to nominally SRF-compatible geometries (e.g. elliptical cross-section structures). In the future, we will explore the use of nested single-gap but isolated structures to provide the benefits of a dual-gap structure.

In the course of determining tuning procedures for the single-gap SRF-type profile radial cavity, we noted the presence of higher-order modes at relatively low multiples of the fundamental mode. Specifically, for a cavity with the fundamental mode at 254 MHz, there is a hexapolar mode at 500 MHz. An exterior view of the cavity, and equatorial cross-sectional views of the electric fields of the two modes, are shown in Figures 1 (a)-(c) respectively. The major axis of the elliptical cross-section in Figure 1(a) is 71 cm; the beam flight tubes are 15 cm long, with 3 cm diameters. The heaxpolar mode is of interest because, for a similar field profile in the gap, it has a Q approximately twice that of the fundamental mode. We are exploring whether there is an advantage to using one mode over the other. Figure 2 shows a comparison of the radial field component as a function of radius, including the beam flight tubes.



(a) (b) (c)

Figure 1: (a) SRF-compatible radial RF injector cavity; (b) equatorial slice showing RF e-field of fundamental mode; (c) equatorial slice showing RF e-field of hexapolar mode.

This model includes 15-cm flight tubes for beam injection into and extraction from the cavity, as a means of providing a transition from room-temperature environments (e.g. cathode, target) to the superconducting cavity. This is a relatively short transition, but experience with other SRF devices operating in the 500-MHz region (e.g. the Mark I and Mark II SRF photoinjectors, developed as a collaboration between the Naval Postgraduate School and Niowave, Inc.) using smaller transitions suggests this is a feasible standoff.

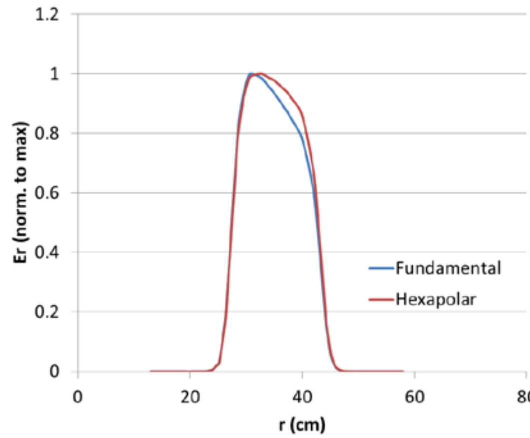


Figure 2: Comparison of the radial electric field of the fundamental (blue) and hexapolar (red) modes shown in Figure 1. The radius r=0 corresponds to the center of the structure. Beam enters the accelerating gap traveling in the –r direction.

We have developed a conceptual model of a gated DC thermionic cathode electron gun, intended to operate in the 20-kV range with average beam currents of up to 0.166 A, to serve as nominal injectors; six such beam sources located at the ends of the flight tubes can together provide an average beam current of 1 A. By applying a frequency comb to the cathode-grid gap, we can generate relatively short (relative to the RF period) beam current pulses, improving injector performance by reducing final energy spread and beam divergence inside the cavity. The original model was developed with the **spiffe** z-r PIC code, and the basic performance preserved when translated to the tracking code GPT. Small solenoids surrounding the flight tubes provide beam confinement during the transport from the end of the flight tube to the cavity. Figure 3 shows a schematic of the beam source configuration. The beam is pulsed, but snapshots in time are overlapped to provide an indication of the overall beam envelope. The gun is operated at 20 kV, with a 1-cm diameter cathode, and a beam emission time of 150 ps and bunch charge of 0.333 nC, corresponding to 0.166 A average current per gun at 500 MHz repetition rate and a peak current of 2.2 A.

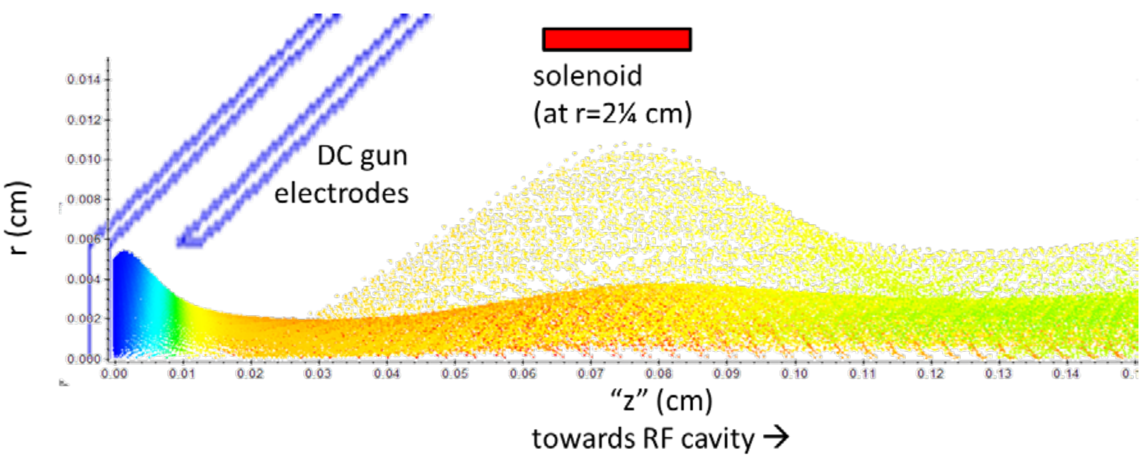


Figure 3: beam propagation envelope from nominal DC gun. Color coding indicates particle Lorentz factor γ; the beam energy spread increases in the drift section due to space charge.

Adoption of a gated DC thermionic cathode gun, if successful, allows elimination of a photocathode drive laser system. The 15-cm standoff distance between the cavity and beam source may provide sufficient distance to include a gate valve, allowing cathode and source maintenance to be performed without venting the SRF cavity; this is an area for further investigation.

Task 2 – Engineering design and analysis

RF power coupler design

While design work on the power coupler has not yet started, the conceptual design of the cavity shown in Figure 1 has been discussed with the RF designer and several options appear feasible, including traditional loop coupling schemes as well as probe-type couplers. For the fundamental mode, in particular, adding ports for probe couplers would appear to be straightforward as an extension of the beam flight tube concept.