DEPARTMENT OF AEROSPACE ENGINEERING

Faculty Name	:	**Dr.A.Arun Negemiya, AP/ Aero**	Academic Year	:	**2024-2025 (Odd)**
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UNIT II - ADVANCED PROPULSION TECHNIQUES

Plasma Thruster

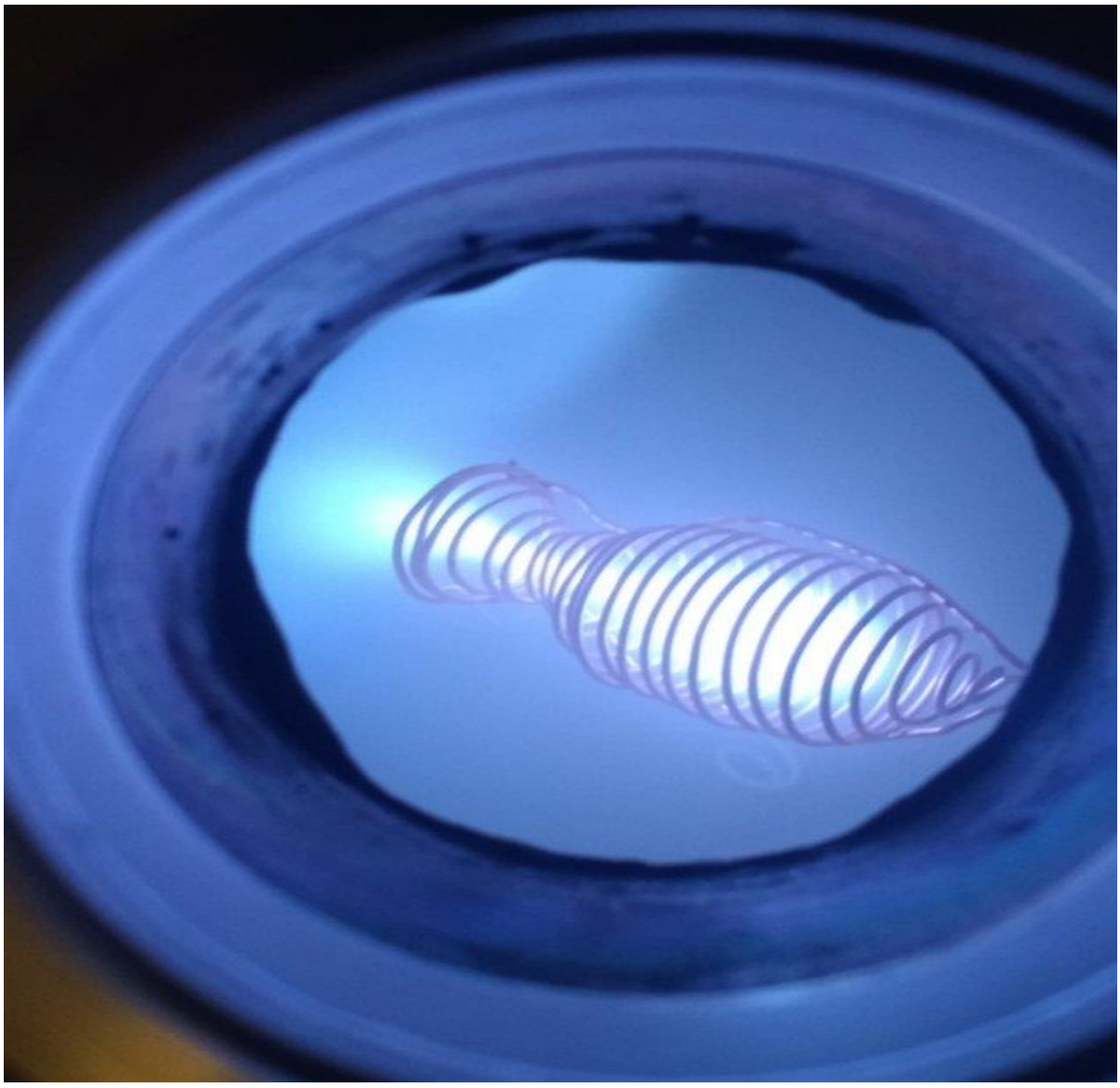

Figure 1. Dense bright plasma within the main chamber is clearly visible.

The engine that I built operates substantially differently but maintains a few core similarities. For starters, there is still a "fuel" and there is a source of heat. The engine also generates thrust by shooting mass out of a nozzle! Of course, the same laws of physics and thermodynamics apply. Now before you get excited about blasting off into space with your brand new plasma rocket-pack, I have to dash your dreams with science. Unfortunately, the thrust generated by this method, and other plasma thrusters, is incredibly small. The record, according to Wikipedia, is currently around 5 Newtons of thrust in a lab environment! The reason they are still used is they are extremely efficient which can be read in more detail in the Further Reading section. I am unable to measure the thrust of my engine with the equipment I have, but it is so small it probably less than .001 Newton.

The propellant that I used for this thruster is simply residual gas left inside of the vacuum chamber. This residual gas drifts about the interior of the vacuum chamber and eventually some of it ends up drifting into the engine body. Since the gas molecules are neutral, they are not attracted or repulsed by the strong electric field surrounding the chamber body(further explained below) allowing them to drift into the cloud of swirling electrons in the center of the engine. These gas molecules are then struck by electrons, turning them into ions which creates the bright plasma. Some of these newly formed ions get carried with the electrons out of the engine body while some collide with the wire and become neutral again. In this sense, the fuel is reusable as long as it drifts back into the engine at some later point in time. The only true input into this system is energy in the form of electric potential and current. Electrons are emitted from the negatively charged engine body and some become trapped within, forming the electron cloud. An additional bonus is that any positive ions that form outside of the engine will be attracted to the negative potential engine, and thus increase the concentration of free gas to be used as fuel near the engine!

Now you may look at my plasma thruster and think "Well there are no walls! How can it hold back the plasma?!". The answer is through a virtual wall, or electric field. The spiral shape that encases the plasma is actually copper wire which is connected to a negative high voltage terminal. This high voltage generates a large negative electric field around the wire coil which repulses other negative charges, such as electrons. This allows you to confine negative electric charges! To help illustrate this point, I am going to use a diagram from one of my previous articles.

Figure 2. The orange lines represent electric field lines and the more there are in a given area, the stronger the field. Note the dark spot within the ring structure

Extrapolating from the Figure 2, we can gather that there will be a low electric field in the center of a coil that is electrically charged. What this does is creates a strong electric field around an area of low electric field which is exactly what you want for containing a plasma! Once charged particles are created near the electric field, they are repulsed into the lower field region in the center of the structure. This occurs until enough particles accumulate that the charge in the center is comparable to the charge containing the particles. By this point, a dense ball of plasma has formed due to the large number of electrons bouncing around. Once they reach this equilibrium point, they look for a weak point in the field to escape. Think of squeezing a half-full water bottle with a tiny hole in the lid. As you squeeze, water fills up the air pockets until it entirely fills the bottle. At this point, the pressure is equalized and if you squeeze anymore, water will shoot out the top. This is very similar to how the Plasma Thruster 1.0 works. Figure 3. displays this plasma plume leaking out of an unintended point due to a bent wire and thus a weak point in the electric field.

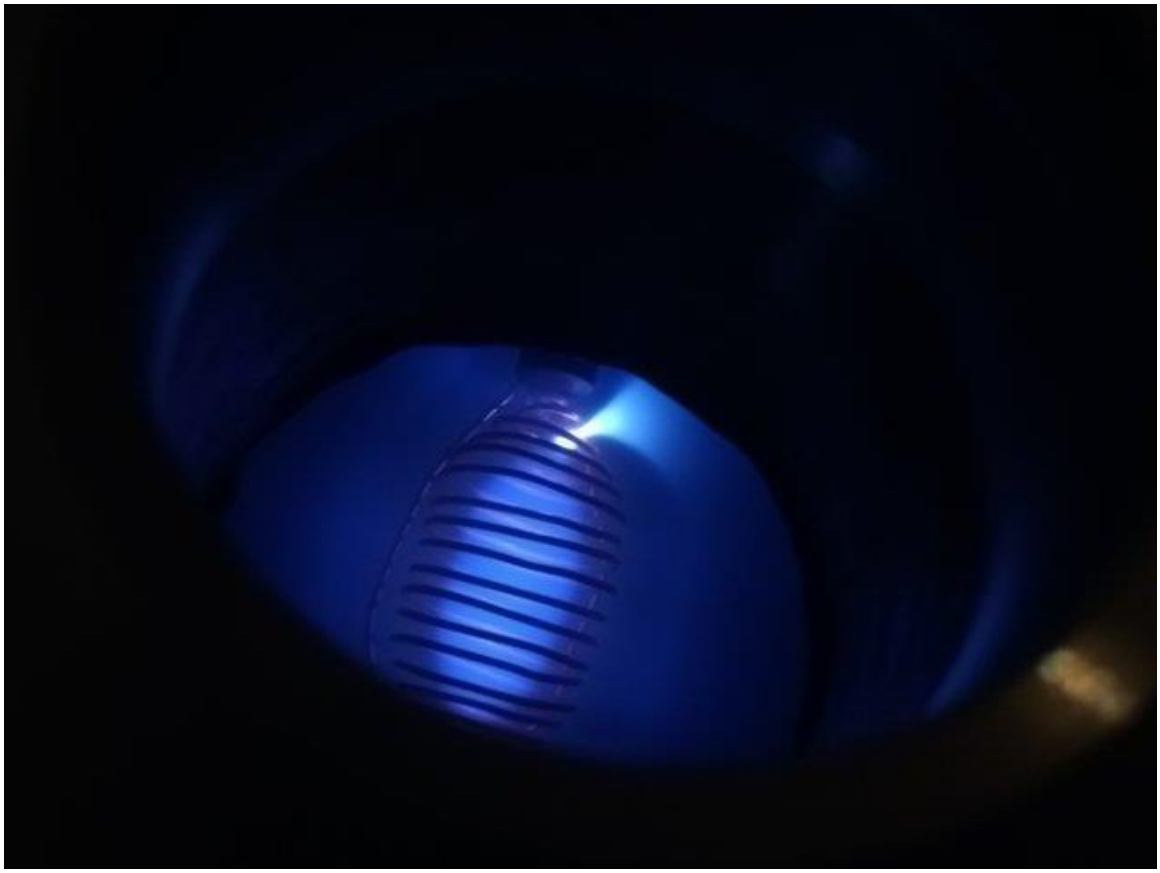

Figure 3. Plasma leaking out the side of the thruster body

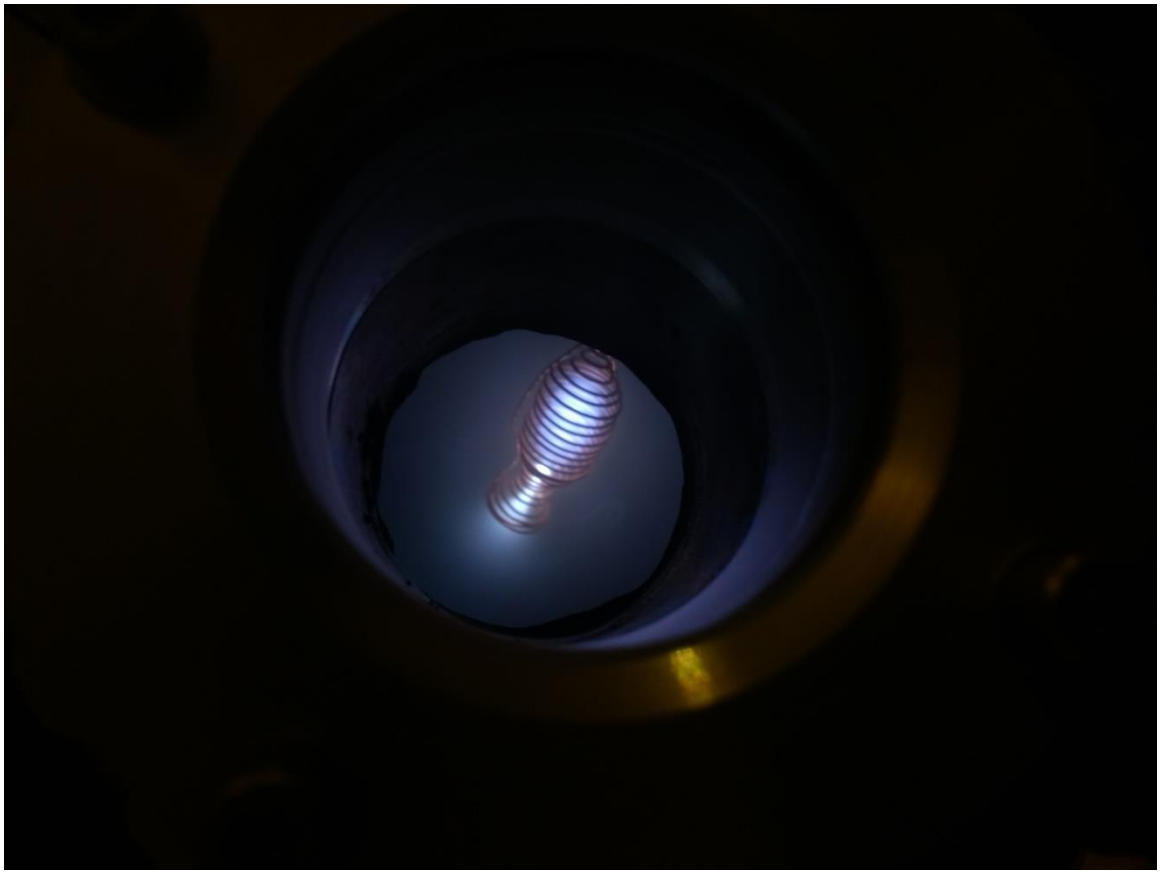

Figure 4. Electrons are accelerated through the nozzle which creates a denser and hotter plasma in the throat (white area)

I showed many of these images in my previous article and an idea came to mind when I was reviewing them. If you artificially make the weak point, you can choose where you shoot the plasma and direct it! This lead to the current design of the plasma thruster. Adding a nozzle keeps the plume directed out and away from main body. There isn't too much to the design other than a little bit of wire wrapping, the physics takes care of itself! Hopefully this was a sufficient explanation of how the Plasma Thruster 1.0 works!

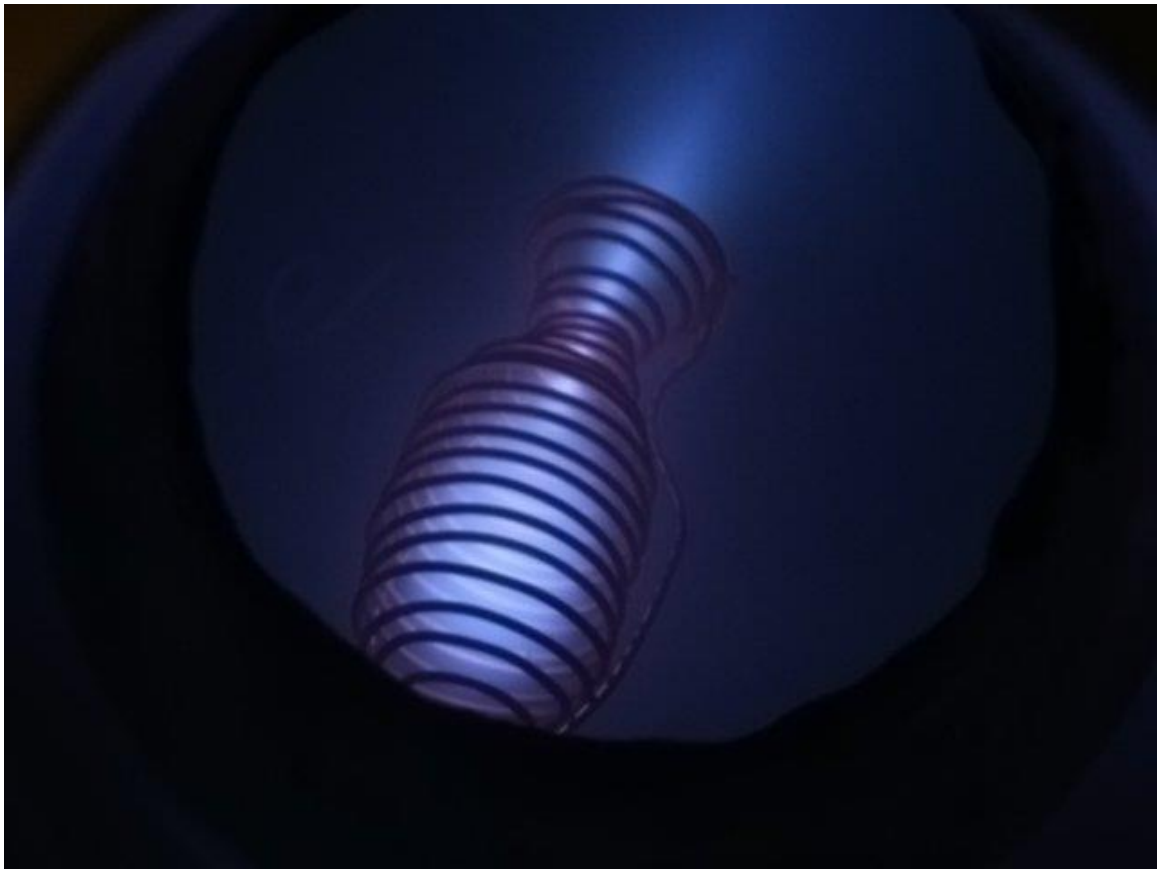

Figure 5. A lower vacuum chamber pressure pushed the flow towards molecular conditions

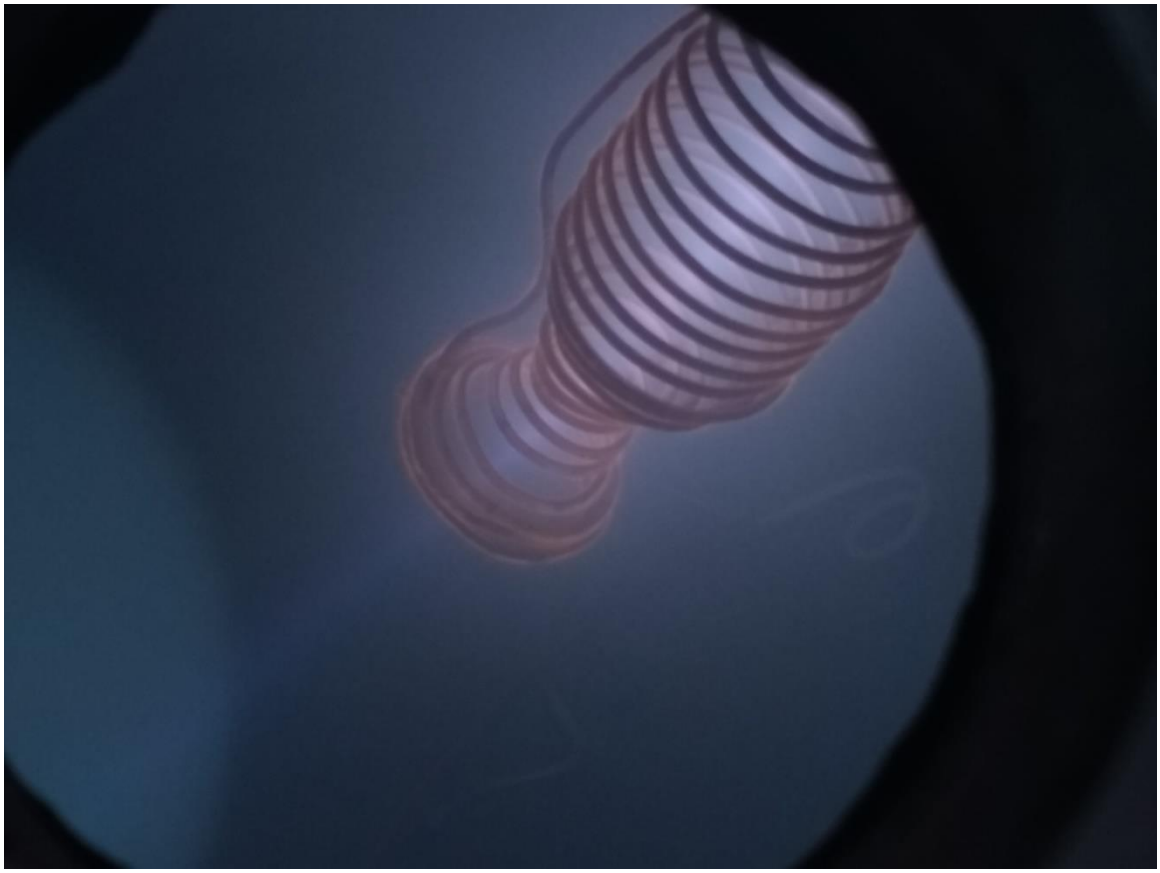

Figure 6. Beam of electrons blasting out from the nozzle due to molecular flow conditions. Note the orange glow coming from the surface of the copper.

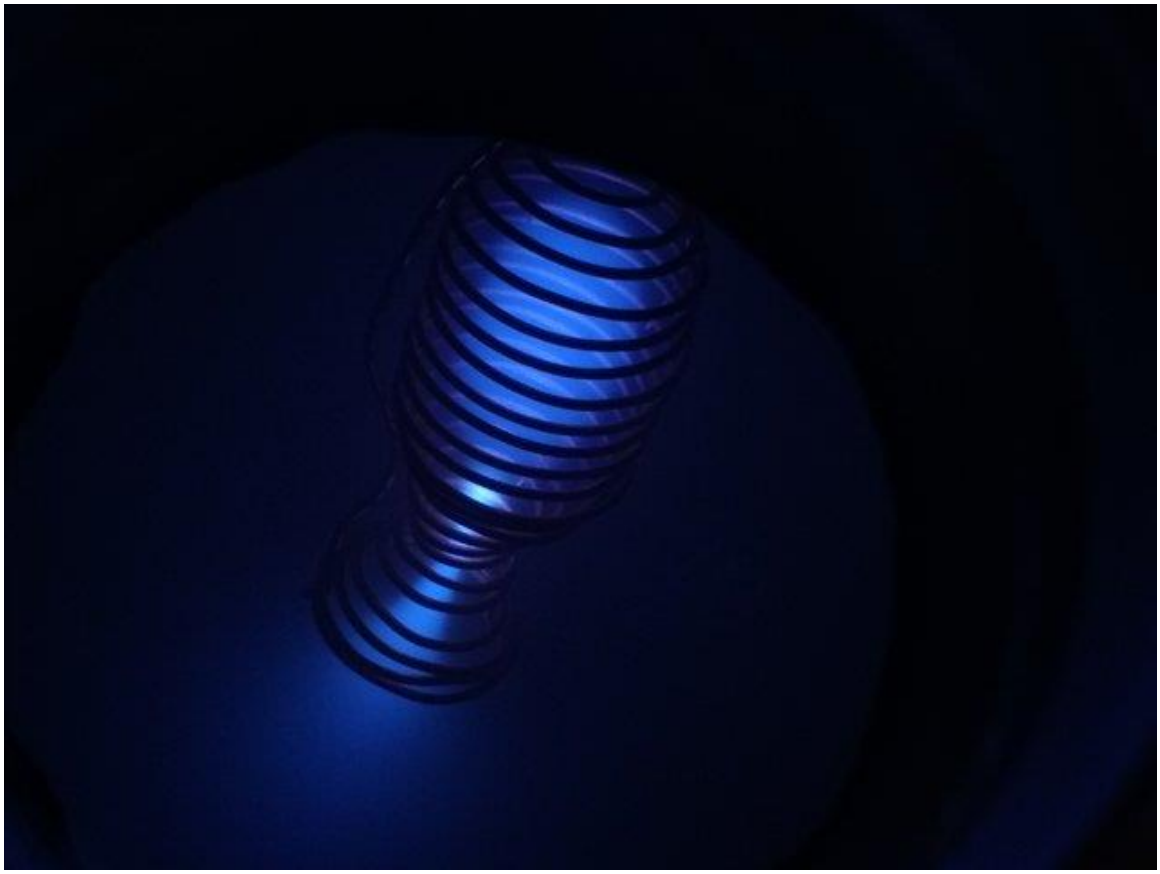

Figure 7. Lower voltage applied than in the other images. The nozzle throat still is a white hot plasma.