Fabrication of laser x-pinch targets

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Abstract
In response to user requests for ultra-thin wire laser-driven x-pinch targets an R&D programme was carried out to establish suitable fabrication techniques. The particular challenge was to produce targets having wire diameter of approximately 5-10 µm. It is difficult to source wire of less than 10 µm diameter and such wire is very challenging to use.

A combination of microassembly and electrochemical etching techniques enabled the fabrication of the requested x-pinch targets with the pinch being a point where two small wires of diameter approximately 5-10 µm cross and are in physical contact. The targets were driven by a laser pulse hitting a 100 µm × 100 µm square thin foil attached to top of the wires.

Introduction
Experiments have indicated that when an x-pinch target is irradiated by an intense laser pulse strong magnetic fields are created at the pinch point of the target. These fields are due to the convergence of the two return electron currents that are travelling through the thin wires. Previously targets have been fabricated using commercially sourced wire of 10 µm diameter and without a driving foil.

An investigation was carried out to find the best way to produce the targets with wire diameters in the range of 5-10 µm.

Three different fabrication methods were trialled using combinations of micro-assembly and chemical etching techniques. The methods were:-

1) Conventional microassembly using thin (~10 µm) diameter wires (which were purchased from suppliers).
2) Using larger (25-100 µm) diameter wires for the assembly of the x-pinch then electrochemically etching the wires before attaching the driver foil.

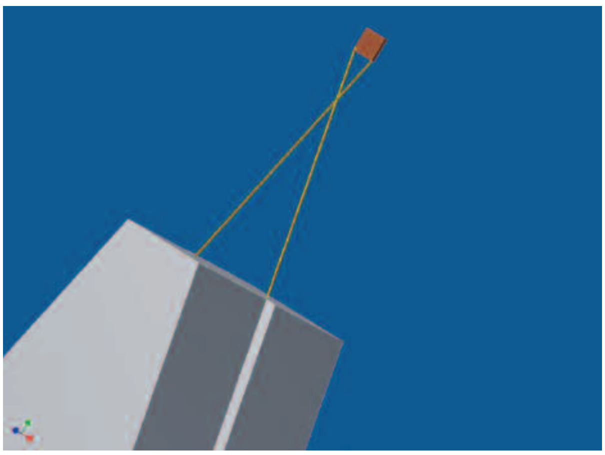

Figure 1. An initial design sketch for an x-pinch target.

3) Electrochemically etching larger (25-100 µm) diameter wires to the required final diameter before assembly.

Initial Electrochemical Etching Investigations
Initially investigations of a range of etch rates and control parameters were carried out. Also the final physical profile of the etched wires was characterised. Furthermore a variety of materials was investigated as early requests from the experimentalist required that the material of the wire used should be high Z (atomic number). Etching tests were carried out on gold, tungsten and titanium wires and they showed that for optimum control tungsten was the most effective material for electrochemical etching using a 2M NaOH solution.

Early test runs showed there was a problem caused by wires etching preferentially around the surface of the solution. This gave rise to a situation where there was a maximum amount of etching that could be achieved along the wire before the region of the wire at the surface etched through and the remainder sank into the etching solution. The minimum etched diameter along the length of the wire (excluding the tip and the surface) was approximately 15 µm before the wire etched through. As wire diameters of less than 10 µm were required a resolution to this problem was needed.

Repeated Dipping to Eliminate Preferential Etching
Trials were carried out in which the wire was not left in the solution while etching but dipped into the solution for 1 second intervals. This dipping process ensured that there was no part that was left at the surface of the water to preferentially etch allowing etched diameters along the wire to reduce to below 8 µm.

A number of different voltages and times were used for the etch and the results of the optimum voltage (of 2V) are summarised below. This voltage was chosen as it did not etch too quickly in relation to the dip time. Time of the etch is based on a dip of 1 second repeated to accumulate the specified etch period.

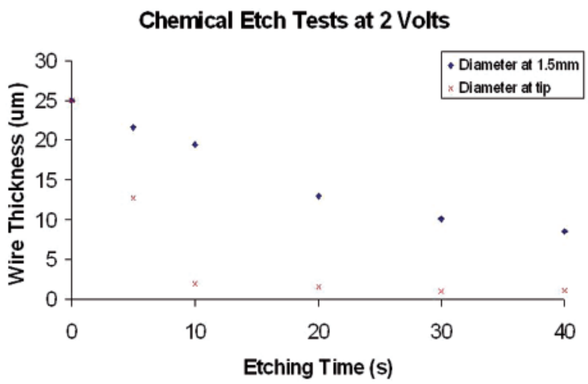

Figure 2. Summary showing time dependant etch characteristics of 25 µm diameter tungsten wire.

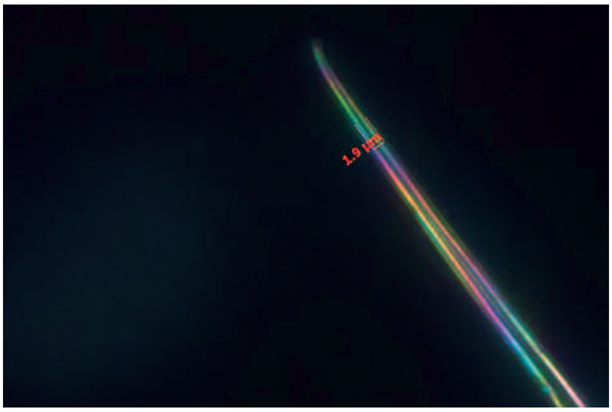

Figure 3. Highly magnified picture of the tip of an etched wire.

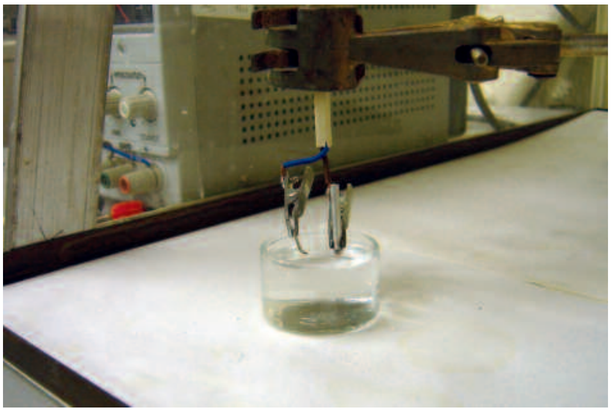

Figure 5. The set-up of the etching apparatus.

1) Conventional Microassembly Techniques

The assembly of microtargets depends on techniques and fine manual skills that have been developed and refined over a number of years. Specific techniques for x-pinch production were:

(i) Commercially purchased wires are supplied wound on a spool. Such wire was cut into pieces and then rolled straight using the correct amount of pressure (for the particular material being used) in combination with suitable rolling surfaces to enables component wires to be straightened without damaging them.

(ii) Jigs were manufactured using ultra precision micro-engineering techniques available at RAL. These jigs were then used to hold components in place while glue was applied to the parts and subsequently cured.

(iii) Assembly was carried out on ergonomic assembly stations by highly experienced fabricators.

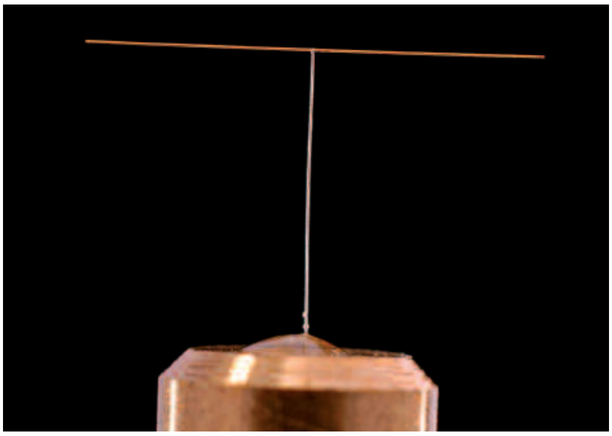

Figure 4. An example of a different type of thin-wire target assembled using standard techniques. (Horizontal wire 25 µm diameter.)

2) Electrochemical Etching of Entire Wire Assembly

Larger (25-100 µm) diameter wires were assembled to form an x-pinch target employing established microassembly techniques (stated above) using pre-machined guides and features on a target stalk. The whole of the wire assembly part of the target is then chemically etched using 2 molar sodium hydroxide (NaOH) before the driver foil is attached.

3) Electrochemical Etching of Wires Before Assembly

The wires were etched separately before assembly into an x-pinch target. The procedure for etching is given above. After etching conventional assembly techniques were used to make the target.

The pre-etched wires were individually straightened using a rolling technique and each one attached to a post. The posts were then mechanically clamped in place and connected to a DC power supply. Each wire on its post was then repeatedly dipped into and withdrawn from the etching solution to achieve the required thinned profile.

Figures 6 and 7. An etched wire that has been thinned to 20 µm along the length and a tip that has been thinned to approximately 1 micron.

Although the wires were pre-straightened it was necessary to straighten each one after etching as well.

Comparative Summary

Each of the methods for the fabrication of x-pinch targets had both desirable and detrimental features.

It is easier to etch a single wire than to etch a completed target since single wire etching enables accurate control of the thickness of the wire without the restrictions that exist by having to avoid damage to the (very delicate) assembled x-pinch targets.

However, although it easier to control the thinning of individual wires it is more difficult to obtain straight wires as they have to be rolled after etching and rolling a thinned wire to be straight is extremely challenging. Additionally the fine tips on the wires are easily damaged during assembly.

Furthermore if assembly is carried out before etching then the wires (because they are thicker) are easier to manipulate into the desired geometry.

Conclusions

Balancing the relative merits of the three trialled fabrication methods the optimum schema has been shown to be: pre-assembly of the x-pinch targets using thicker (~100 µm) diameter wire and then etch the whole assembly using the repeated dipping method before attaching the foil to complete the target.

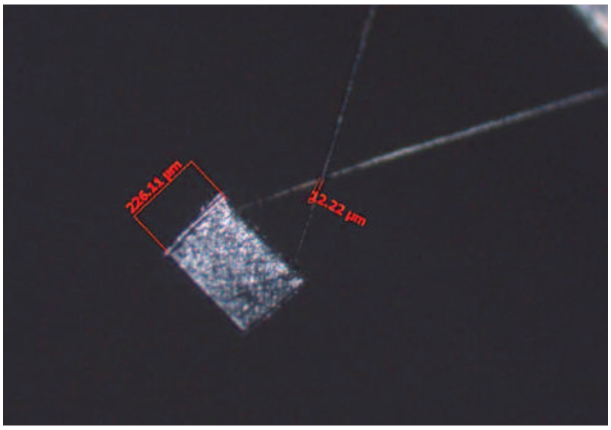

Figure 8. A completed (trial) (not fully-thinned) x-pinch target showing attached driver foil.

The x-pinch targets were made for an experiment run on the Vulcan laser system in January 2007.