Development of Automated Fabrication Processes for High Repetition Rate Micro-targetry

Contact *James.Mills@stfc.ac.uk*

James Mills, David Haddock, Sam Astbury, Chris Spindloe, Martin Tolley

Target Fabrication Group, Central Laser Facility, STFC Rutherford Appleton Laboratory, Harwell Campus, Didcot, OX11 0QX

Paul Amos

Electrical Engineering Group, Central Laser Facility, STFC Rutherford Appleton Laboratory, Harwell Campus, Didcot OX11 0QX

Mark Williams

Diamond Light Source, Diamond House, Harwell Science and Innovation Campus, Fermi Ave, Didcot OX11 0DE

Introduction

This paper details the Target Fabrication Group project to develop automated fabrication processes for micro-targetry. These targets are to be used on the Gemini laser system in the CLF and are fabricated autonomously using two robots running independently: one to pick and place target foils, and the other to glue lines/dots upon which the target foils are to be placed.

As laser repetition rates increase, there is more demand for micro-targetry to support experiments. Finding rapid and repeatable ways to fabricate these targets will reduce the strain placed on staff who carry out the fabrication and quality assurance processes. This, in turn, will allow more time for the development of new capabilities within our laboratories, aiding experiments in the near future through improvements in the quality and rate of micro-targetry fabrication.

Targets Assembled Using Automated Fabrication

Figure 1 shows an example of an array target used in operations and which has greatly benefited from automated fabrication processes. Some human monitoring is required, but the robotic system can successfully fabricate these array targets. Firstly, the injection robot dispenses glue, as shown by the dotted lines, before a second robot picks up the metallic foils and places them over the apertures. The glue is then cured with UV light by staff once the process is complete. The automated process has reduced the process time from two hours when completed manually, to less than 20 minutes.

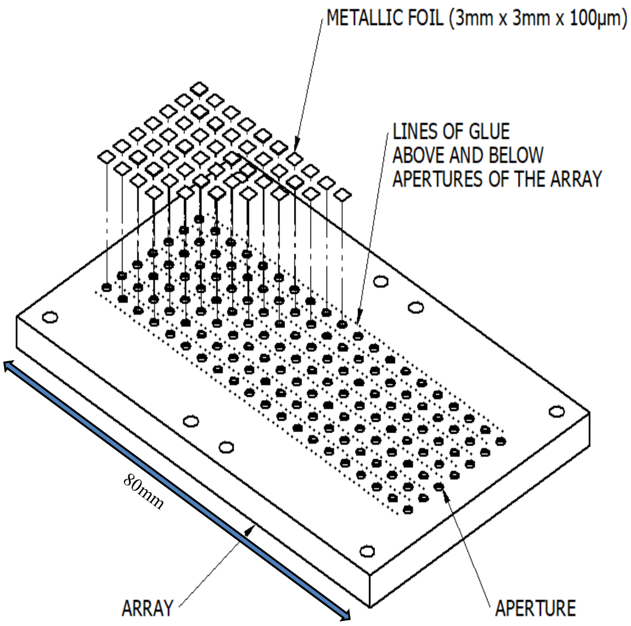

Figure 1: Schematic of a high repetition-rate target array manufactured using a robotic system

Automation Capability in Target Fabrication

The Target Fabrication Group uses a Mitsubishi RV-1A [1] six-axis robot with gripper hand. A bespoke fixture has been attached that holds a manual vacuum pen, which can transport various types of target foils using a light suction force.

The Group also uses a Fisnar FN4200N [2] glue-dispensing robot, connected to a dispensing controller. Glue is dispensed using a needle manufactured in-house. This robot holds the target arrays shown in Figure 1.

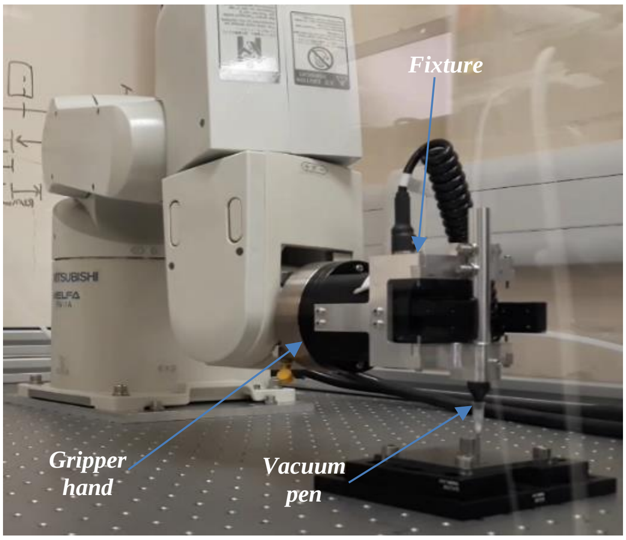

Figure 2: Mitsubishi RV-1A robot with gripper hand, attached fixture and vacuum pen. The robot is shown picking up a metallic target foil from an arbitrary position.

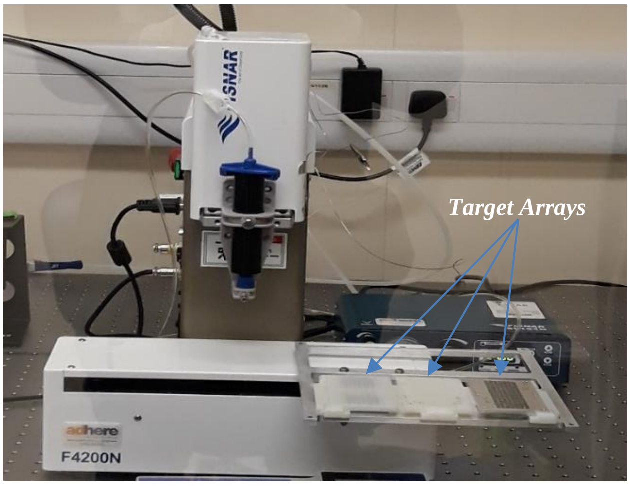

Figure 3: Fisnar FN4200N: the injection head has y and z travel and the sample tray has x travel; fully programmable to allow for complex dispensing patterns.

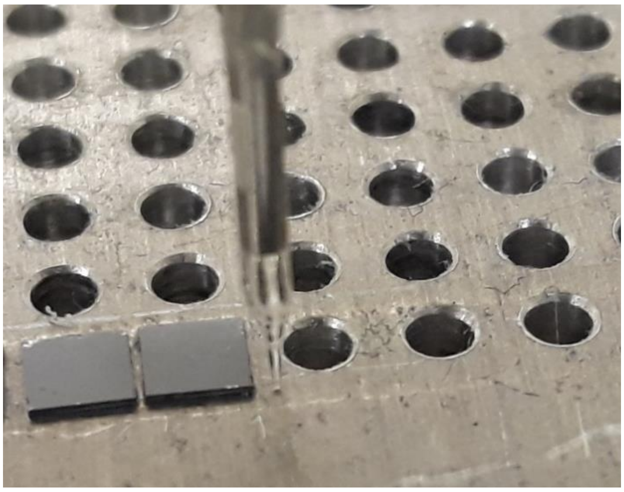

Figure 4: Target array with two targets adhered using glue dispensed from the needle tip shown

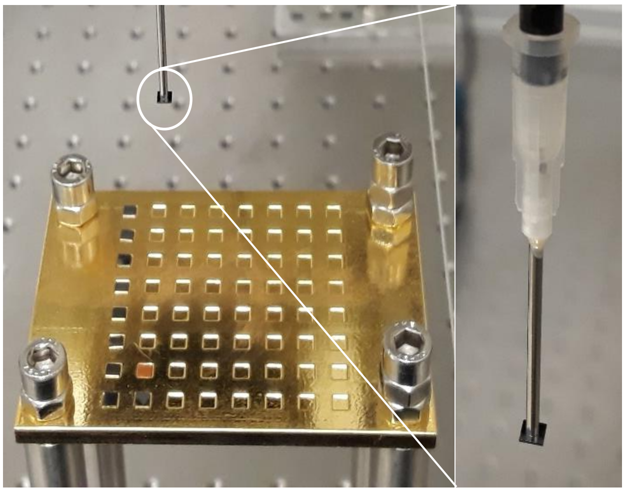

Figure 5: Gold coated, 3D-printed target foil tray. Shown is a pallet of 8 x 8 indents used to locate targets, along with some test silicon or copper targets. The needle tip is shown picking up a silicon target ready for transport to a target array.

Challenges with the Current Automated Method

The current automated method is restricted in the types of micro-geometries that can be assembled. There is no in-process feedback loop, so the robot is unable to verify successful ‘pick and place’ operations. Additionally, there is no in-process quality assurance for the system, so there is no way to evaluate data collected and then make process adjustments during system downtimes. Currently, the robots are only position repeatable to 20 µm, limiting assembly of targetry to these precisions under ideal conditions.

With the RV-1A robot, the Target Fabrication Group has had trouble finding or manufacturing components that will aid the transport of target foils in a repeatable manner. The vacuum pen that is currently used is manually operated and its suction force cannot be controlled beyond an ‘on/off’ state. This lack of control can affect the placement of targets over apertures, as the pen must be actuated to remove the suction force and deposit a target, causing excess air, held in the pen, to blow onto the adjacent targets, occasionally moving them out of position when the glue does not have adequate contact with the target . Even with static charge being significantly reduced on the tray in which the targets are held, the vacuum pen does not pickup and carry targets with ideal levels of repeatability, the current level of 80% repeatability is significantly higher than with previous versions of the setup.

With the FN4200.N robot, the quality of the dispensed glue lines depends on various factors that affect how the glue will flow. Quality variations can be limited by choosing a low viscosity glue, and minimizing the time between dispensing lines, placing targets and curing the glue. A further problem is the time needed to readjust the program when the needle tips or the glue-containing tubes are replaced. Because the needles are so small and brittle, and no reliable method to manufacture consistent geometry needles has yet been established, staff must adjust the program to achieve adequate quality glue lines every time a new needle is installed.

Quality and Repeatability of the RV-1A Robot

To improve the repeatability of the ‘pick and place’ process using the RV-1A robot, a bare needle has been attached to the vacuum pen to reduce any frictional forces acting on the targets when being picked and placed. A target foil tray has been designed and 3D-printed, as shown in Figure 5. The tray has square indents, a few hundred microns deep, to position the target foils, which allows users to set the program to move the robot to these points, locating the target foils. Coating a thin layer of gold onto the model using a sputter coater has helped to eliminate buildup of static charge. This is a significant improvement, because with the small masses of the targets being used, static and frictional forces have a larger relative effect than gravity [3].

Quality and Repeatability of the FN4200.N robot

To reduce the amount of glue dispensed on the metal array, capillary needles are manufactured and bonded to a metal needle, dispensing lines of glue down to 700 µm wide. This thickness is enough to provide adequate bonding between the target foil and the array without being excessive, leading to glue showing through the bottom of the aperture. This would result in a defective micro-target. The engineer responsible for the system determines if the width of dispensed lines is acceptable, and checks that the needle does not drag along the surface of the substrate, as this could cause it to break.

To increase the maximum number of target arrays that can be fabricated in one cycle, mounts have been designed to hold six target arrays on the glue dispensing robot.

Future Developments

Future work is concentrated on installing a camera into the system, which will be used to determine the location of target foils and direct the Mitsubishi robot to pick them up. The camera will also provide useful quality assurance data on whether a target foil has been lost in transit (using feedback to direct if the robot needs to go back to the same aperture with a new target foil it has picked up) and whether targets are being placed in the correct orientation.

Data collected from this camera can be used to analyse the repeatability of the current process setup for the various target foil materials, and engineers can perform post-processing on data logs to identify ways to improve the process further.

Conclusions

Automation methods developed by the Target Fabrication Group have been used to successfully fabricate array targets with satisfactory levels of repeatability. Current methods require some operator input, namely repositioning some misplaced target foils and manually UV curing.

Future work is focused on developing more defined processes for the manufacture of basic micro-targetry, with capabilities and reliabilities far beyond what is currently available. Use of data collection equipment, such as a camera and other sensors, will help to define and optimise the automated system, delivering the same level of flexibility provided by Target Fabrication staff, but with improved fabrication times, higher repeatability and greater precision.

References

1. RV-1A/2AJ Series Standard Specifications Manual (CR1-571 Controller) – Mitsubishi Electric
2. F4200N Operating Manual – Fisnar

3. Fearing, R.S. (1995). Survey of sticking effects for micro parts handling. Proceedings 1995 IEEE/RSJ International Conference on Intelligent Robots and Systems. Human Robot Interaction and Cooperative Robots, 2, 212-217 vol.2.