# IN-SITU TARGET SURVEYING FOR INK-JET PRINTING OF FUNCTIONAL MATERIALS

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## INTRODUCTION

Ink-jet printing technology has long been used in applications outside of text and image printing on the desktop and in large formats. Examples include medical test chips, display phosphors and backplanes, layers of solar cells, printed circuit elements in general, microlens arrays, adhesive or solder seals and 3D objects.

In ink-jet printing, droplets of ink are generated using thermal or piezoelectric actuators at a close distance above the target surface, typically 0.5-2 mm. Commonly used droplet volumes range from a few pL to over 100 pL, with up to about 1 nL in a few instances. The ink may represent the bulk material to be dispensed and accumulated in the target structure (e.g., microlenses), or the fluid component of a solution or suspension may serve only as a carrier for the material of interest (display phosphors, conducting powders, medical reagents).

Control of the dispensed amount of the material of interest can involve various aspects and methods: ink composition, droplet volume, droplet mass, immediate inspection after printing. Furthermore, correct placement of the dispensed material is an item of serious concern. In some applications, the surface to be printed on is not flat, so some means of feeding surface profile information into the printing process is needed.

Here we will discuss the integration of a laser distance sensor on an ink-jet printer to measure the height of the surface underneath the sensor and thereby the print head. Reading a height at a certain location in the plane can be organized just like placing a droplet, allowing us to handle the laser sensor much like an ink-jet dispenser. Thus our printer architecture lends itself easily to such an extension.

## SCANNING THE TARGET SURFACE

We first looked at mapping the surface of a printing target for a project aimed at printing skin components onto large area burn wounds. This involves complex sequences of dispensing living cells, structural material and nourishing solutions onto the wound. Ink-jetting offers a suitable level of volume dosing per unit area. The shape of the wound surface is not a priori known, so it needs to be measured in time for the application of the reconstructive materials. As the print head must be able to scan over the full area anyway, adding a surveying element for mapping the height profile to the print head offers a convenient way to obtain the needed surface map.[1] The geometric relations between the dispensers and the distance sensor can be determined well and are stable. A concept for a gantry-style surveying and printing system is shown in Figure 1, and the scheme of acquiring a map in Figure 2.

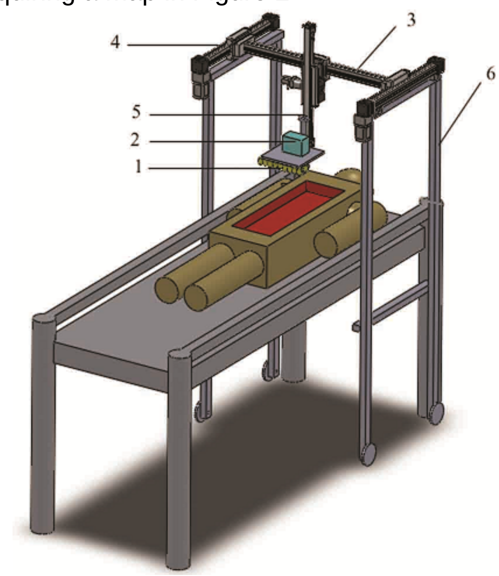


*FIGURE 1. Concept for printing skin onto burn wounds. 1: Cartridge-based fluid delivery system, 2: Laser scanner; 3: Mobile frame; 4-6: X, Y and Z axes. (From ref.[1])*

While we start out with a compact laser distance sensor that strictly measures only vertical distances, a more complex sensor arrangement with, e.g., 3D laser scanners may become necessary, and a system could take the form of a classic large CMM with both a laser scanner and a print head fitted to its surveying stage (Figure

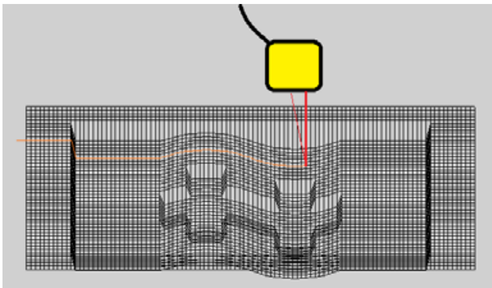

*FIGURE 2. Concept of a surface scan, using a target model from ref.[3].*

3).[4] In either case, the resolution needed in the height measurement is around or above 100 $\mu$m, and the laser beam spot sizes, over which some form of averaging occurs, can be of the order of 1 mm$^2$. To set the application scale, cells can have 20 $\mu$m diameter, so placement to about 100 $\mu$m is adequate and needs to be accomplished over an area of possibly as large as 0.5-1 m$^2$.

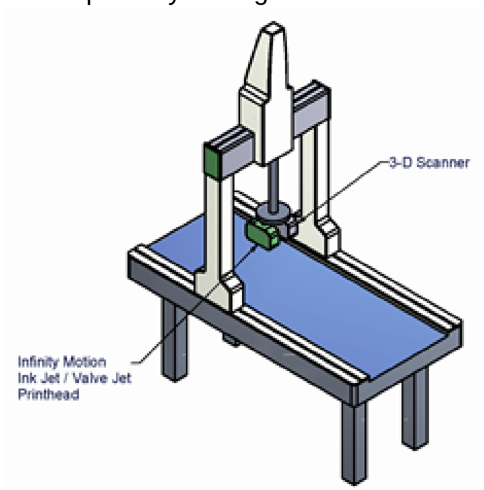


*FIGURE 3. CMM with 3D scanner and print head. (From ref.[4])*

A detailed print head design for dispensing multiple materials as needed in the skin repair printer project is shown in Figure 4.

The particular application of surveying and printing onto burn wounds has some additional complications (the height or depth of the missing skin tissue must be estimated, and the target can be moving as it belongs to a breathing human[2]), but the concept applies well to printing a priori designed structures (lines, coatings, lenses, ...) on stable inanimate targets (Figure 5).

Integration of a laser scan head can use the same

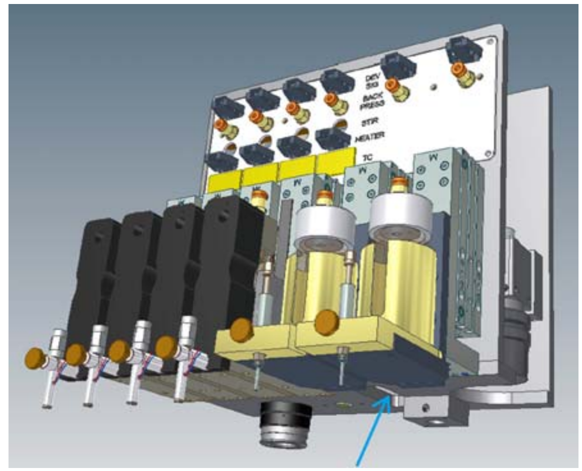

*FIGURE 4. Print head for skin repair printing. Each dispenser can be lowered individually for work, in order to otherwise stay clear of any surface structure. The arrow indicates the location for the laser distance sensor for surface profiling.*

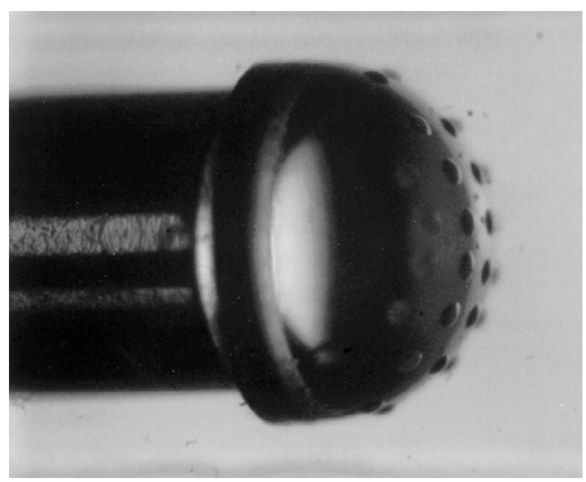

*FIGURE 5. Microlenses printed onto a larger lens. No surface mapping was used in this early feasibility test at MicroFab Technologies, Inc., rather, the printhead was kept at sufficient height to stay clear of the target.*

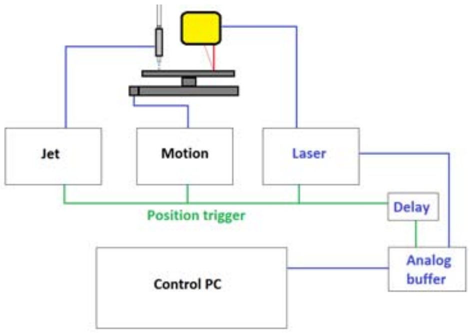


*FIGURE 6. Coordination between the motion, laser and jet controllers for acquiring a surface map and subsequently printing on it.*

scheme as printing during motion ("on the fly"): The position feedback system produces trigger signals that can be fed to either a print head or the laser scan head (Figure 6). The commercial laser head that we use (Panasonic HL-G108[5]) can hold the readings in analog form until the next trigger arrives, thus allowing for time to convert the analog signal and store it in a buffer (MCC USB-7202 analog I/O module[6]). Once the scan of the object is complete, the control PC of the print station loads the stored data, converts them into print instructions, and moves the print head over the object. Figure 7 shows a move of a laser head over a truncated pyramid that keeps the separation to the surface constant, with the surface shape having been surveyed just before by that laser head moving at constant absolute height. With a full print head assembly like the one in Figure 4 above in place of the bare laser head, a dispenser would move the same way with its tip close to the target surface.

**SCANNING THE PRINTED OBJECT**

In more conventional printing applications, like printed optics or electronics, the inclusion of a laser distance sensor can be of benefit, too. An example for a printed structure of significant height from an earlier MicroFab project to print lenses from multiple materials is shown in Figure 8.

The available range of performance parameters, in particular the spot size, vertical resolution and repeatability, allows mapping of the shapes of printed objects on top of the target surface. For example, a printed silver line of 50 mm length, desired resistance of 1 $\Omega$, and 250 $\mu$m width, would have to have a height of 20 $\mu$m or more (requiring multiple passes), assuming a resistivity 6 times

*FIGURE 7. Move of the laser head (in lieu of an inkjet dispenser) following the mapped profile it has produced just before.*

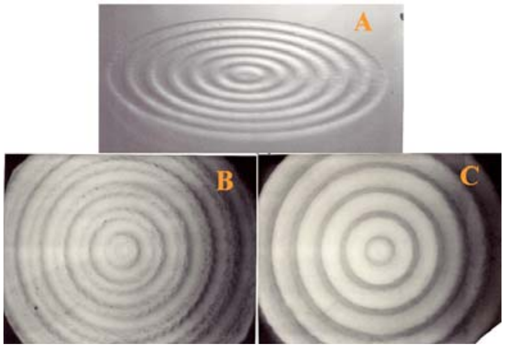


*FIGURE 8. Rings of optical material 620 $\mu$m wide and 70 $\mu$m high. Views: A: perspective at 50°; B: focused on substrate plane; C: focused on ring-focus plane.*

higher than bulk for the printed silver. Thus a sensor with 100 $\mu$m spot diameter and 2 $\mu$m repeatability, which is commercially available (we use a Panasonic HL-G103[5]), can be applied to control the progress and end point of the printing process (Figure 9).

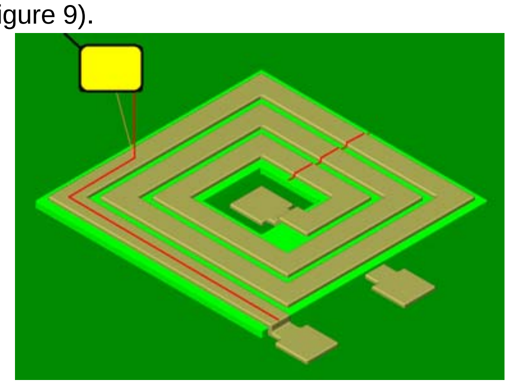

*FIGURE 9. Scan of height and width of a printed conductor (adapted from ref.[7]).*

A first implementation will use scans across a single conductive line at multiple locations along the line to monitor the cross section, which together with the a priori comparatively well known line length and the material properties determines the total resistance of the line.

## CONCLUSIONS

In summary, integration of a laser distance sensor with a print head on an ink-jet printer allows both to establish the actual target surface just in time for printing and the control of the progress and end point in multi-pass printing applications. The fixed geometrical relationship between the coordinate measurement and printing devices reduces registration problems between the two tasks to a minimum. The general benefit to ink-jet printing of digital control and ability of producing objects in small numbers, down to lots of 1, is extended to changing target shapes and production quality is improved.

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