Square Dot Printing with Xaar-Type Inkjet Printheads

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Abstract

Equipping each ink channel with four nozzles allowed to print 'square dots' onto the substrate and to match the dot shape to the square pixel area on the substrate. Advantages of 'square dot'printing are cost savings by efficient usage of ink ('thin ink') and print quality. Square dots from large drop printheads further yield a considerable increase in print throughput.

Introduction

A basic problem of inkjet printing is the fact that the ink drops produce round dots on the paper, while the pixels to be addressed are square by definition. Instead of one nozzle per channel it is possible to equip each channel with multiple nozzles, so that in principle non-round dots can be produced on the paper.[1,2] With appropriate design of the printhead actuator as well as the nozzle plate 'square dots' can be printed onto the substrate, which fill out the square pixel area well. Prerequisites are simultaneous drop formation and same drop velocity of the individual drops from each nozzle as well as controlled trajectories of the propagating drops, which must not join during flight.

Multiple Nozzles per Ink Channel

The multi-nozzle concept was investigated with Xaar's XJ500-360 and XJ126-200 inkjet printheads as test vehicles. These are piezo inkjet printheads based on the shear-mode shared-wall principle, and both are end-shooter types.[1] The ink channels are vertically positioned within the active PZT wafer at a high linear density of 141μm (XJ500) and 137μm (XJ126) pitch. The nozzle plate typically contains single nozzles of diameter 42μm (XJ500-360) and 50μm (XJ126-200) to deliver nominal ink drop volumes of 40pl and 80pl, respectively.

The influence of multiple nozzles per channel on the total ink drop volume was evaluated with printheads containing four nozzles per channel. 4x20μm, i.e. four nozzles of 20μm, were placed at a grid of 35μm on otherwise standard XJ500-360 printheads. The total ink drop volume of the four individual drops was constant at 33pl up to printing frequencies of 8kHz. 4x25μm nozzles resulted in 55pl total drop volume without any sign of starvation up to 8kHz printing frequency.

Tests with larger drops were carried out with the XJ126-200 printhead. Placement of two 35μm nozzles on each channel did not show any dependency of the total ink drop volume of 80pl on nozzle distance. Two 50μm nozzles produced 140pl total volume, however, strong reduction in total drop volume occurred at printing frequencies beyond 2.5kHz. To avoid such channel starvation at very high ink drop volume a modified ink channel geometry with wider ink channels was used.

Providing wide channels but maintaining the pitch of the XJ126-200 required reduction of the channel wall thickness below the standard 62μm width. Printheads with 35μm wall width were used in the subsequent print tests. In order to analyze the manufacturability of thin-wall actuators several printheads were built with an even lower wall thickness of 28μm, and the thin walls proved to be stable in all manufacturing process steps.

A concern with thin channel walls was potential de-poling of the PZT-walls. Long-term print tests were therefore conducted, during which the printheads with 35μm channel wall thickness were driven with waveforms of up to 35V amplitude. This corresponded to electric field strength of 1 kV/mm within the channel wall, and was expected to depolarize the PZT channel walls. However, no depoling was detected, and these 35μm printheads continued to produce ink drops of specified drop velocity after the end of the test at 5 billion drops per channel fired.

The reduced mechanical stiffness of the thin channel walls resulted in a lower resonance frequency. As a consequence the maximum printing frequency of the modified XJ126 printhead with 35μm wall thickness was 4.9 kHz as compared to the 5.2 kHz of the standard XJ126-200 printhead.

Such modified XJ126-200 (35μm wall) printheads were equipped with different nozzle plates, containing single or multiple nozzles of different diameters per each ink channel. Total ink drop volume measurements demonstrated that a single nozzle of 56μm diameter delivered 150pl drop volume with no indication of channel starvation up to the highest print frequency of 4.9kHz. This is about twice the ink drop volume of the standard XJ126-200 printhead. Up to 175 pl total drop volume and only slight channel starvation was observed when printing with 4x 28μm nozzles, i.e. four nozzles of 28μm, on the otherwise identical printhead. From these data it was concluded that the modified XJ126 printhead with 35µm wall thickness is a capable device for printing very large drop volumes.

'Square Dot' Printing

Drop formation studies of printheads with four nozzles per channel demonstrated that the individual drops were simultaneously formed and that they propagated with the same velocity. The drop trajectories were found to diverge slightly and it appeared that the divergence was larger for the modified XJ500-360 printhead. The divergence was analyzed by printing on glossy paper at 1mm print distance, measuring the distance between the dots, and comparing with the spacing between the four nozzles in the nozzle plate. The data indicated that the four drops from the 4x25µm nozzles considerably diverged at low drop velocities and decayed to 1.1 degrees off normal at the nominal drop velocity of 6m/s. The drops from the XJ500-360 printhead with 4x20µm nozzles per channel exhibited a lower divergence of 0.6 degrees off normal at nominal speed. It was assumed that the lower divergence was due to the fact that the four nozzle cones were separated, while they partially overlapped in the case of the 4x25µm nozzle arrangement. For the four 40pl large drops from the XJ126 (35µm wall, 4x28µm nozzles) printhead only a small divergence of 0.2 degrees off normal was analyzed. These four nozzle cones were completely separated by 12µm at the nozzle cone inlets.

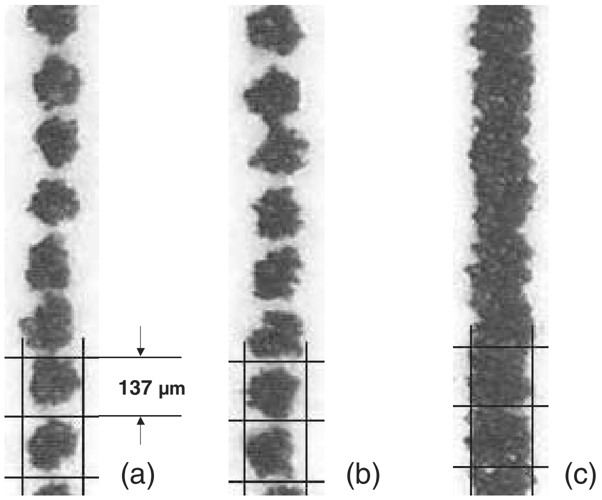

Figure 1. Lines printed onto HD125 paper in 185dpi mode with (a) single drops of 75pl, (b) single drops of 150pl, and (c) four drops of 175pl total ink volume per ink channel.

Specifically the printouts on glossy paper and high resolution paper revealed the high quality dot placement of the four individual droplets and the formation of 'square' dots obtained with the XJ126 (35µm wall, 4x28µm nozzles) printhead. The advantage of 'square dot' printing became obvious when printing lines with different XJ126 printhead versions on HD125 high resolution paper (see figure 1). With the single drops of 75 pl per channel from a standard XJ126-200 printhead only the dotted lines in figure 1(a) could be printed in 185 dpi mode. With single large drops of 150 pl the quality of the printout improved only slightly, and a dotted line prevailed in figure 1(b). Only when printing with four drops per channel from the XJ126 (35µm wall, 4x28µm nozzles) printhead a solid line of true 185dpi size was obtained as seen in figure 1(c) in spite of an almost identical total drop volume of 175pl. This striking improvement in print quality was attributed to the more even distribution of the ink volume across the square pixel area.

The XJ126 (35µm wall, 4x28µm nozzles) printheads worked reliably in wide-format printers in 185dpi mode, and the optical density of their printouts compared well with those of standard XJ126 printheads working in 300dpi mode. Taking into account both the increase in printed area and the slightly reduced printing frequency, this results in a 2.5 time increase in print throughput for the square dot and large drop printhead.

Conclusion

Four nozzles per ink channel were placed on Xaar-type piezo inkjet printheads to produce four individual drops per channel with total ink drop volumes in the range from 33 to 175 pl. The four individual drops allow to distribute the ink on the substrate and to form a single square dot that fills the square pixel area. Advantages of 'square dot' printing are cost savings by efficient usage of ink ('thin ink'), and print quality (e.g. for bar-codes). 'Square dot' printing with large drop volumes further resulted in considerable increase in printing throughput.

References

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Biography

Werner Zapka is currently manager of Advanced Manufacturing Technologies at XaarJet AB. He obtained a PhD in physics in 1980 at the Max-Planck-Institute, and then worked in research and development in IBM US and IBM Germany until 1995 when he joined MIT Inkjet as manager of Manufacturing Process Development.
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