Femtolitre drop generation in industrial inkjet printheads.

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Abstract

In this paper we report what we believe is the first-time observation of femtolitre drop generation from a nozzle in an industrial inject printhead. While femtolitre drops have been observed and reported, it has been mostly in the context of jet ligament thinning and subsequent breakdown into drops by Rayleigh-Plateau instability. This communication will show jetting of femtolitre size drops directly from the ink meniscus formed on the nozzle exit of two different industrial printheads. The printheads are from different manufacturers, with different microchannel and piezoelectric structures, and the two inks used are very similar, one of them having one extra polymer component used to increase the ink viscosity. The jetting events happen at random times, from immediately after the ligament detachment from the nozzle up to several hundreds of microseconds later. While the physical mechanism underlying this jetting phenomena is not understood, we will analyse our results and compare with existing theories small drop formation, to try to build an understanding of how this jetting process work.

Introduction

Industrial commercial inkjet printheads are widely used in printing and manufacturing processes where non-contact printing or variable data printing offer an advantage over contact fixed image printing. As printing technologies are a key enabler of many microfabrication processes, inkjet printing is finding wider applicability and acceptance in different and novel microfabrication processes. To meet the needs of the graphics industry and due to some engineering considerations related to the physical mechanisms used for drop ejection, industrial inkjet printheads have been designed to jet drops of volumes ranging from ~1pl to ~200pl. While this range is well suited for imaging, text and decoration applications, some microfabrication applications require smaller drop sizes down to the femtolitre volume range. A physical phenomenon that can generate femtolitre drops is therefore of great interest, as it could potentially be engineered into a device that can jet femtolitre drops on demand and be used in non-contact microfabrication processes.

Methods

To visualize femtolitre drops we needed to develop a sub-micron resolution stroboscopic drop microscope, commonly known as a dop watcher. The device we developed is now commercially available as a Meteor UltraSharp Optics drop watcher. The optical magnification of the microscope objectives used were x20 and x50, with numerical apertures of 0.42 and 0.55. The light strobe was a 452nm blue light LED with a pulse duration of 200ns.

Results

To visualize femtolitre drops a dop watcher was used. Nothing special was done to generate the drops, as they seem to occur spontaneously sort after a typical picolitre drop is jetted and its ligament has detached from the nozzle, for time durations of several hundreds of microseconds after this event. The drop size has some dependency on how the picolitre drop is generated. Typical waveform jetting picolitre drops at speeds of a few meter per second created these secondary drops of 1um to 2um in diameter. Slower drop waveform(~1m/s) can create, in addition of the 1um to 2um drops in diameter, drops with diameters of 3um to 6um.

Femtolitre drop generation in Ricoh Gen5

Femtolitre drops being ejected form a Ricoh Gen5 printheads can be seen on Figure 1 below. The drops start to appear from a few microseconds after the detachment of the main picolitre drop up to several hundreds of microseconds afterwards. Single, double and triple drop ejection have been noticed all across this time scale.

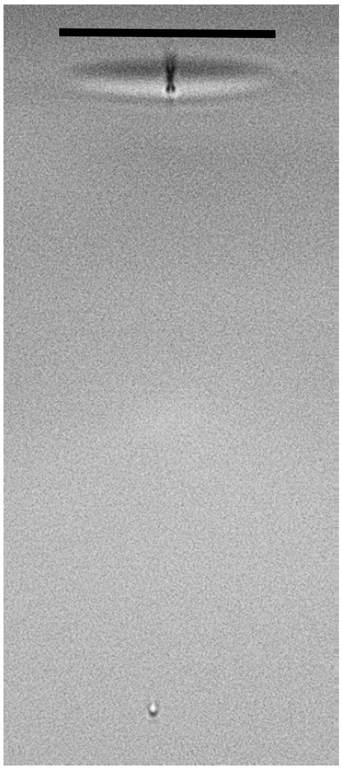

Figure 1. Femtolitre drops being ejected from a nozzle of a Ricoh Gen5 printhead. Black line is the same dimension as the nozzle diameter, 25um. Single flash exposure photograph.

Femtolitre drop generation in Dimatix Samba

Femtolitre drops being ejected form a Dimatix Samba printheads can be seen on Figure 2 below. The drops start to appear from a few microseconds after the detachment of the main picolitre drop up to several hundreds of microseconds afterwards. Single, double and triple drop ejection have been noticed all across this time scale.

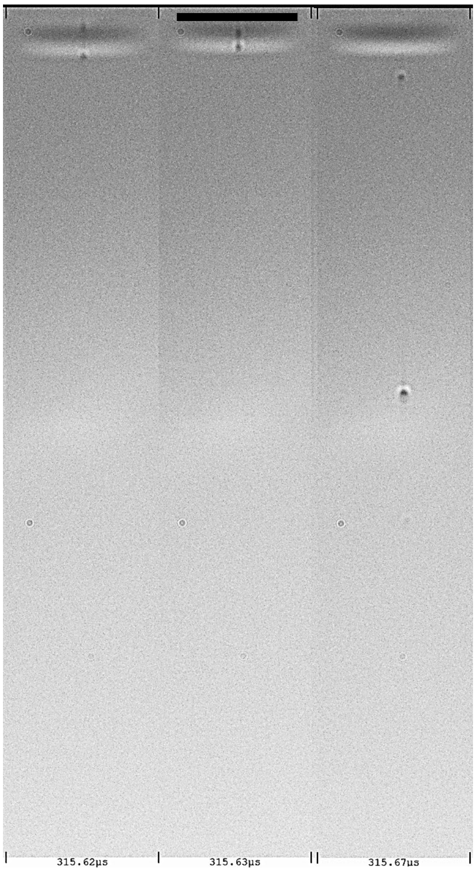

Figure 2. Femtolitre drops being ejected from a nozzle of a Dimatix Samba printhead. Black line is the same dimension as the nozzle diameter, 25um. Single flash exposure photograph, 300us after nozzle waveform excitation. The last frame shows two femtolitre drops jetted close in time to each other, at about 300us after the waveform actuation was finished.

Femtolitre drop generation in Ricoh Gen5 printheads

Two different sizes femtolitre drops being ejected form a Ricoh Gen5 printheads long time after the main drop ligament detachments (see Figure 3). A detailed view of the drops emerging form the nozzle can be seen in Figure 4.

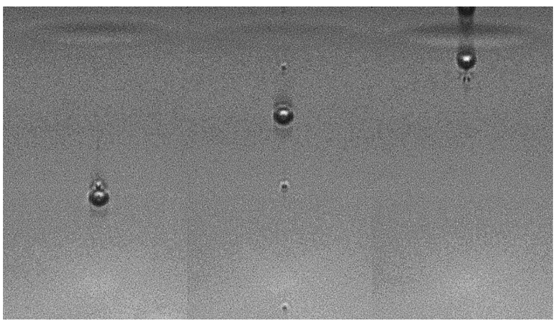

Figure 3. Two different sizes femtolitre drops being ejected from a nozzle of a Ricoh Gen5 printhead. Small drops are ~1fl to ~10fL, bigger drops ~100fL.

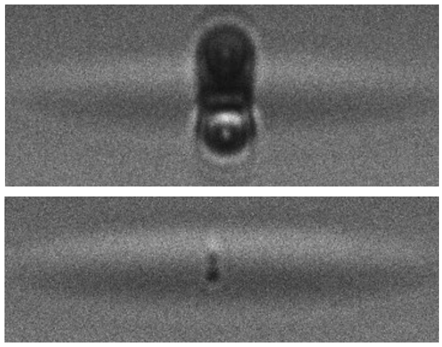

Figure 4. Detail of the moment of emergence from the nozzle of two different sizes femtolitre drops being ejected from a Ricoh Gen5 printhead.

Discussion

The ejection of femtolitre drops from two industrial inkjet printheads, Ricoh Gen5 and Dimatix Samba, has been detected shortly after the main drop filament detached from the nozzle until several microseconds later. The ejection seems to happen multiple times after one main drop (picolitre) ejection, at what appear to be random time intervals. Sometimes two drops are seen being jetted very close together.

Although it has not been possible to measure the drop velocity directly, this can be inferred for low blur caused by the 200ns light strobe. Form this we estimate the drops speeds to be of a few meters per seconds maximum.

Different size femtoliter drops can be generated by changing the jetting speed of the main picolitre drop. Smaller drops can generate bigger size femtolitre drops. Even when this is the case, smaller (1 to 10fL) drops are also generated.

Conclusion

This paper shows for the first time the ejection of femtolitre drops from the ink meniscus boundary of two industrial inkjet printheads. Although the underlying ejection mechanism is not currently well understood, we hope this result will raise the interest in this jetting mechanism and its potential for on demand femtolitre drop printing.

Acknowledgement

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This Author Biography

Fernando Rodriguez Llorente received his MSc and PhD in physics from the University Complutense of Madrid (1993, 1999). Since then he has worked in Research and Technology for electrical metrology, ultra long haul fiber optic communication, ultrasound non-destructive testing, big-data algorithm development and multiple aspects of inkjet printing for the last 15 years.