Miniaturized High Speed Visualization Setup for the Diagnostics of Dynamical Processes in Microsystems

H. Brugger, C. Maier and E.P. Hofer

Dept. of Measurement, Control and Microtechnology
University of Ulm, Albert-Einstein-Allee 41, 89081 Ulm, Germany

ABSTRACT

For the real time visualization of the dynamics of MEMS it is often inevitable to use high speed camera systems because of the optical enlargement. The micro diagnostic system MinVis, which consists of a miniaturized optical setup with a commercial microscope objective and a high performance AlInGaP LED as pulsed light source allows the investigation of these highly dynamic processes in microsystems in real time, and represents an economical alternative to complex and very expensive high speed camera systems. The application of MinVis covers a wide range from diagnostic measurements during the prototype development to inspections for the quality assurance of microsystems. As an easily transportable setup MinVis is also particularly suitable for presentation purposes.

Keywords: high speed visualization, dynamic processes in microsystems

1 INTRODUCTION

Dynamic processes in MEMS (micro electro mechanical systems) are in general very fast due to their small masses. Additional, because of the small sizes, an optical system magnification is required. The consequence of this optical enlargement is a virtual speed-up of the mechanical system. Therefore, for the real time visualization of the dynamics of MEMS it is often inevitable to use multi frame high speed camera systems.

The micro diagnostic system MinVis allows also the investigation of highly dynamic processes in microsystems in real time, and represents an economical alternative to complex and very expensive high speed camera systems. Fast processes on the micrometer scale are visualized in real time with multiple exposure LED (light emitting diode) illumination while the camera shutter is continuously open. Even non-reproducible processes can be captured since the multiple flashing produces a superimposed image containing real time information.

Such a micro diagnostic system can be used for the determination of unknown material parameters on the micrometer scale, for the evaluation of the system performance and for its optimization. Because of its small size and the modular mechanical-optical structure a single MinVis system or the combination of several MinVis systems can be integrated for e.g. monitoring manufacturing processes [3].

2 COMPONENTS OF MINVIS

MinVis consists of a miniaturized optical setup with a commercial microscope objective and a high performance AlInGaP LED as pulsed light source. LED light sources have already been applied to high speed photomicrography since they have several advantages compared to classical approaches using Xenon flash lamps or spark sources. They have a much higher repetition rate which is necessary for the real time capturing by multi exposures. In order to work with the low light level of the illumination a very sensitive black and white television CCD (charged coupled device) camera is used. Its minimal illumination is specified with 0.00015 lux. Moreover, this surveillance camera has a very compact size. To become a truly movable and versatile high speed real time photomicrography system we have also miniaturized the necessary delay and pulse electronic. Figure 1 shows the optical part of MinVis with the microscope objective, an optical system and the small camera. On the left side the LED light source is visible which is composed of a LED and a lens. The whole mechanic optical part of MinVis is about 240 mm long.

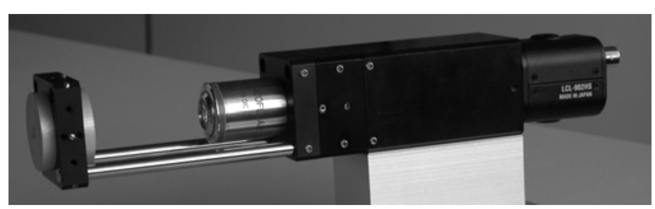

Figure 1: Mechanic optical part of MinVis.

3 FUNCTIONAL DESCRIPTION

For image capturing a standard video camera is used. Therefore the entire measuring procedure is synchronized concerning the black and white video signal from the camera. The CCD inside the camera have to be illuminated within a defined period of the vertical synchronization signal. With an adjustable time value T0 the starting time of this active time period is defined. This time value can be entered with a resolution of 10 μs. According to this trigger signal two high precise time delays are generated. The time basis for these time delays is a 100 MHz crystal oscillator. Thus, the resolutions for these two time delays are 10 ns. Usually, with time delay A the DUT (device under test) is triggered, whereas time delay B triggers the illumination circuit. Figure 2 illustrates schematically the time delays.

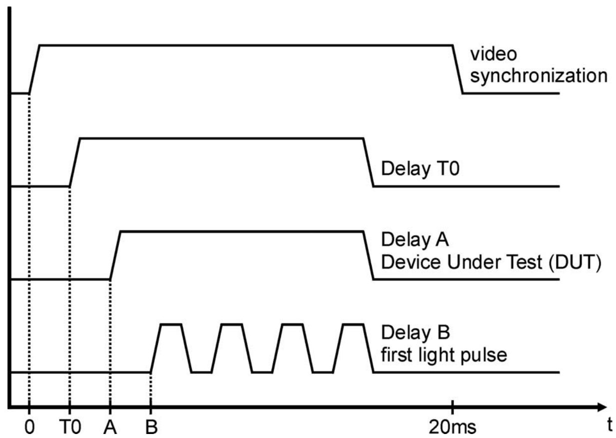

Figure 2: Schematical time delays regarding to the video synchronization.

This illumination circuit produces light pulses with a high performance AlInGaP LED. The number of light pulses, the illumination duration and the time distance between the light pulses are user selectable. The main spectral density of the used LED is at the wavelength of 626 nm. At this wavelength the camera is most sensitive. Within the optical path a matched interference filter is mounted. This interference filter allows the use of MinVis in common laboratories without the need of a shaded environment and prevents an exposure of the CCD during the whole video clock by the background illumination. The resolution for the duration of illumination is also dependent on the used crystal oscillator and is also 10 ns. If there are two MinVis systems necessary, e.g. for the examination of an experiment in two different directions, an optical decoupling with two different wave lengths by the use of different LEDs and interference filters is also possible [2].

For highly reproducible procedures, MinVis is suitable for pseudo cinematographic measurements. Therefore, only one light pulse is used for each captured picture. The dynamic information can be obtained with an increasing time delay B for the light pulse in subsequent pictures. For such measurements, the delay and pulse electronic has implemented an automatic counter for producing such an increasing series of trigger signals. With a video capturing card the dynamic behavior can be saved like a slow motion recording. The speed of the dynamic variation is defined by the increment value to the time delay B for the light pulse.

MinVis is developed as an easily transportable setup. Thus, the whole pulse and trigger electronic is developed as a small device with a standard RS232 interface to a personal computer. The second version of MinVis includes also a frame grabber for the standard video signal and communicates with the PC with an USB interface. The use of standard interfaces for the communication offers the usage of a Laptop for the control of MinVis.

4 HIGH SPEED VISUALIZATION OF A MICRODOSAGE PROCESS

To demonstrate the performance of MinVis, a commercial micro dosage unit [1] is mounted on a xyz-positioning unit and the ejected droplet is in the focus of the MinVis system. Figure 3 shows this measurement setup with the Microdrop dosage actuator and MinVis.

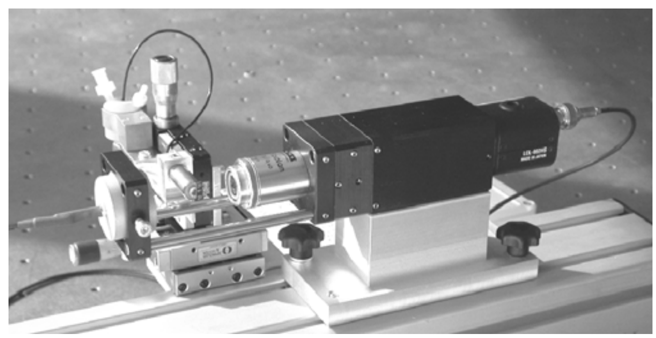

Figure 3: Commercial micro dosage unit as DUT for MinVis.

The Microdrop dispenser heads are designed to process a wide range of different liquids. The inner nozzle diameter is 50 μm and the usual dosing volume is about 65 pl. These values depends strongly on the used liquid. The droplet velocity is in the range of 2.5 m/s with a range of flight of about 20 mm. The Microdrop dispenser uses a glass capillary which is surrounded by a piezo actuator. For different liquids it is necessary to adjust the applied signal to the piezo actuator. There is a rectangular signal with the voltage and width of the signal as parameter. Figure 4 shows on ejection of a droplet, whereas the parameter for the ejection are consciously not optimal. Thus, after the main droplet there exist a tail behind it which alters to an oscillating satellite droplet.

The light pulse for the illumination is 150 μs after the trigger signal for the actuator. The light pulse is 300 ns long. This value is a compromise between a good signal

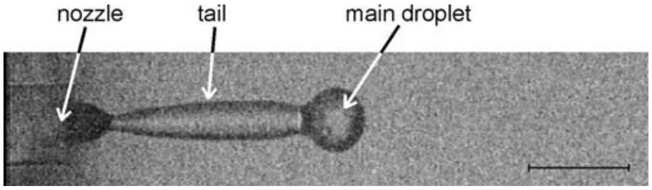

Figure 4: One light pulse for illumination. A main droplet with a tail is ejected by a micro dosage actuator. The bar in each figure denotes a distance of 100 μm.

to noise ratio and blurring effects due to the movement of the object. In Fig. 5 the same ejection is depicted with two light pulses. The second light pulse is shot 50 μs after the first light pulse. The main droplet resides normal and the tail becomes an oscillating satellite droplet. This satellite droplet has a greater velocity and will catch up the main droplet.

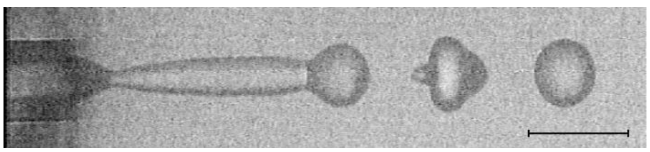

Figure 5: Two light pulses. The tail becomes a satellite droplet behind the main droplet.

The contrast in Fig. 5 is inferior to the contrast in Fig. 4 so that Fig. 5 is brighter than the other one. By the use of more light pulses the sensor accumulates more light and defines the maximum number of light pulses. With optimal parameters for the dosage process, a droplet ejection with 5 light pulses is presented in Fig. 6. The first light pulse is 170 μs after the trigger for the actuator and the subsequent light pulses comes with a time delay of 50 μs.

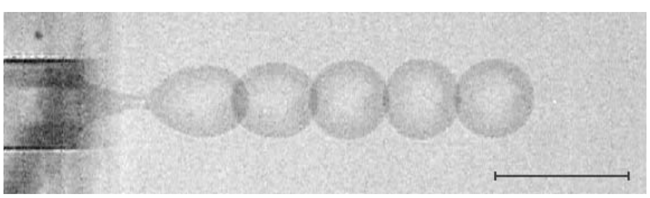

Figure 6: Five light pulses with optimal parameters for the dosage actuator. There are no satellites.

The more highly the number of exposures the smaller becomes the contrast of the captured image. Up to a number of 10 light pulses there is no problem with the contrast. In general, 10 captured moments are usually sufficient, particularly with regard to the limit of 8 pictures of common high speed cameras.

There are also limits for the usage of MinVis. If the dynamic of an object has to be captured in real time, there has to be a characteristic movement in the plane. If there is for example only a rotating device, it's not possible to separate the individual exposures in the captured image. Such an experiment can only be captured by MinVis in a pseudo cinematographic manner. But this means, that the experiment have to be reproducible and in particular that the experiment can be triggered by an electric signal.

In comparison to high speed camera systems, MinVis has several advantages. A high speed camera, like the Imacon468 from DRS Hadland Ltd. consist of eight intensified CCD units which are arranged in a circle around a beamsplitter. There are always discrepancies in the captured images because its not possible to get a perfect optical path for all CCD units. For the illumination a powerful flashlight source is needed and cannot be triggered with high frequencies. Furthermore, for the readout of the captured images an extra I/O-card for a PC is needed. MinVis allows high repetition rates also for non reproducible events and can be watched on a monitor. Furthermore, there is no need for additional hardware.

As mentioned above, MinVis allows also the visualization in a pseudo cinematographic manner. Figure 7 shows 10 pictures of a flying droplet with one satellite. The given time is the delay between the trigger for the dosage actuator and the trigger for one light pulse. The pictures are single frames of an captured video with a PCMCIA frame grabber card. The whole movie shows the flying droplet and the collision of the satellite droplet with the main droplet in a slow motion video. In particular the oscillations of the satellite droplet can be realized very good. In contrast to Fig. 6 its not one and the same droplet. For Fig. 7 ten different droplets are captured with different delay times B for the light pulse. Because of its high reproducibility, it seems to be one moving droplet.

5 GRAPHICAL USER INTERFACE

The graphical user interface is developed with the graphical development environment LabView from National Instruments. This allows the user to enter the necessary parameters for MinVis in a comfort manner and the generation of special series of trigger impulses can be adapted easily to the device under test. The input parameters are sent via the interface (RS232 or USB) to the electronic unit. This circuit generates the trigger impulses for the device and the LED independet from running processes on the computer. Also with the available graphic functions of LabView, some graphic enhancements on the captured image can be carried out. Figure 8 shows the graphical user interface of MinVis with a captured image of the dosage actuator with two light pulses. After a calibrating measurement with a

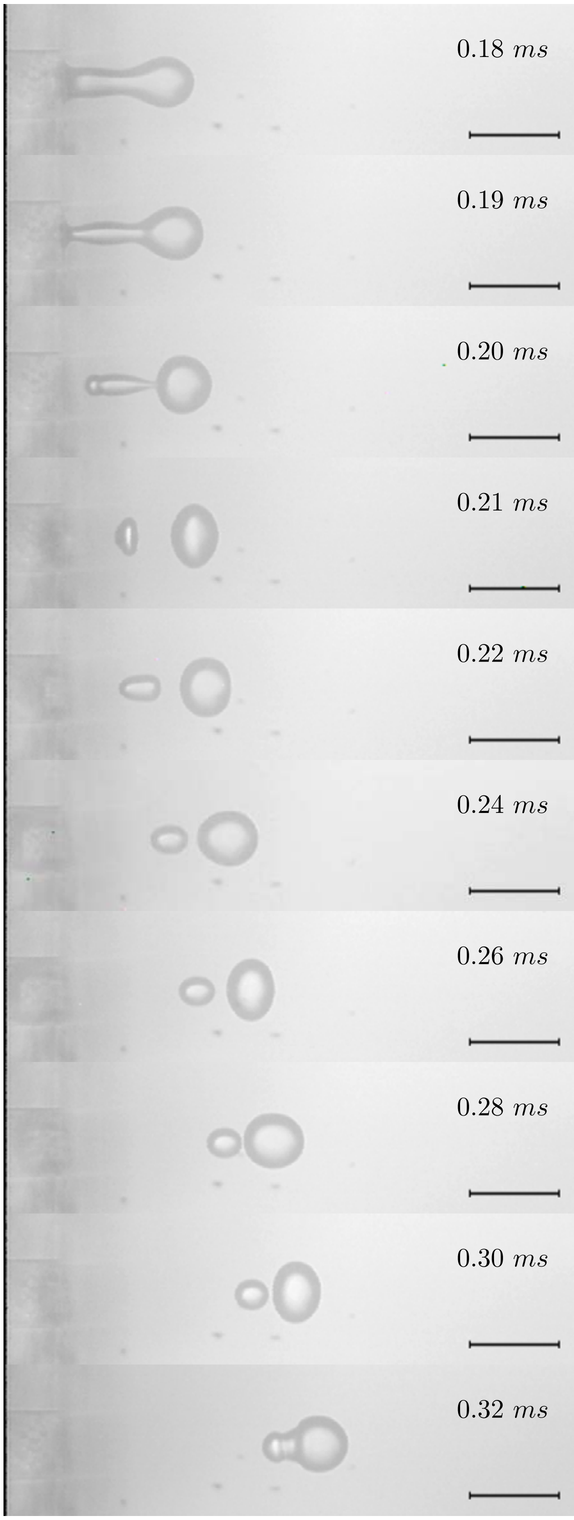

Figure 7: Pseudo cinematographic visualization. The bar in the figure denotes again a distance of 100 μm.

reticle of lines, direct measurements in the image can be carried out. In Fig. 8 the diameter of the ejected droplet is determined with approximately 48 μm.

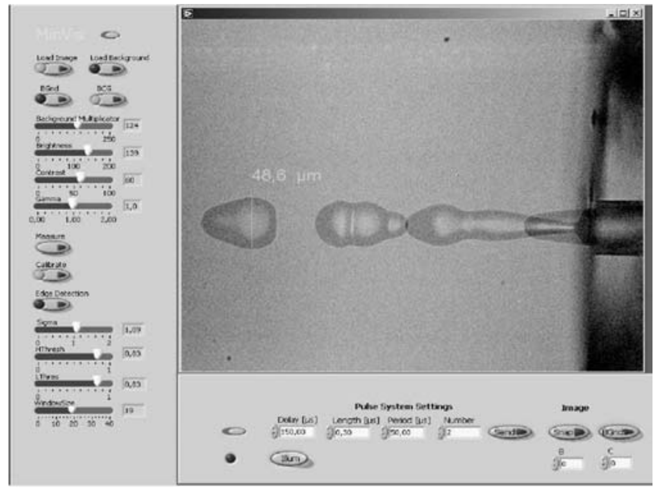

Figure 8: LabView GUI.

6 CONCLUSION

The portable realtime micro diagnostic system MinVis is aimed for the inspection of dynamical processes in micro electro mechanical systems (MEMS). Therefore, MinVis visualizes the motion of small devices in real time by flashing the device with one or more short light pulses. The real time information is recorded in one single superimposed picture. The MinVis system with its components and the performance of this measurement setup is demonstrated on a microdosage process. Thus, MinVis facilitates the investigation of dynamic operations and the identification of system parameters like velocities but also dynamic parameters like eigen frequencies.

With the presented characteristics, MinVis is well suited as a cheap alternative for complex and expensive high speed multi frame cameras and can be used as a easily manageable system for a lot of different applications like supervising, identification, optimization, manufacturing, presentation, and so on.

REFERENCES

[1] http://www.microdrop.com

[2] Maier, C. and Hofer, E.P.: Three-dimensional device characterization by high-speed cinematography. In proceedings of SPIE conference: Microsystems Engineering: Metrology and Inspection. Vol. 4400, pp. 16–22, Munich, 20. June 2001, Germany.

[3] Hofer, E.P. and Maier, C. and Brugger, H. and Wecker, T. and Queffelec, X.: MinVis & Stereo: High Speed Visualization for the Diagnostics of Dynamical Processes in Microsystems. Developed at the department of Measurement, Control and Microtechnology, University of Ulm, Hannover Industrial Fair, Germany, 2002.