

Microscope-on-chip using micro-channel and solid state image sensors

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Recently, Jet Propulsion Laboratory has invented and developed a miniature optical microscope, microscope-on-chip using micro-channel and solid state image sensors. It is lightweight, low-power, fast speed instrument, it has no image lens, does not need focus adjustment, and the total mass is less than 100g. A prototype has been built and demonstrated at JPL.

Keywords: microscope, micro-channel, image sensor, optical microscope.

Optical microscope is an important instrument for NASA's in-situ exploration. To exam the soil and rock sample, and to search for trace of microbes on Mars or other planets, a miniature light weight, fast speed microscope, is very desirable for better, faster, cheaper missions.

Here I report a new technology invented at JPL, a miniature optical microscope using a micro-channel device and a solid image sensor. It can eliminate the optical system of a conventional microscope and eliminate the focal plane adjustment. It is a small size, lightweight, low power instrument, and is able to handle big volume of samples with fast speed. It could be a powerful tool for NASA's in-situ exploration, such as searching life on Mars.

The basic structure of optical microscope has not been changed for hundred years. These optical microscopes are designed for human eyes, because human's eyes can not distinguish small objects, the image has to be magnified first by a complex optical system. Most of the conventional microscope weights at least several pounds, while for NASA's application, a lightweight microscope is desired. In addition, each time when a sample is loaded, the focus of a conventional optical microscope has to be adjusted to have a clear image, it is time consuming, especially when there are lot of samples to be examined.

Now solid state image sensors have replaced the human eyes in many areas. The pixel size of solid state sensors has already come down to around 2 microns. In couple of years, the pixel size may reduce further, even can be close to the optical limit of the best optical microscope. Therefore, if we can make a one-on-one mapping from a sample to the pixels of a solid state sensor, then we would have an electronic image with resolution of the pixel size (two microns or smaller), and this is a miniature microscope without image lens and focus adjustment.

Two year ago, I reported a new technology of "Optical image of highly scattering medium using narrow angle filter"⁽¹⁾. When a highly collimated light is incident on a scattering sample, the scattered light will spread to all of the directions, while the unscattered light will follow the original direction, therefore a micro-channel can be employed to take image through a scattering medium. The geometry is shown in fig. 1. A narrow angle filter, which only allows photons travel along the original direction, while absorb the photons travel along the other directions, is put behind a sample. Only the unscattered light can pass through the filter and an image can be taken for the highly scattering sample. The narrow angle filter, which has many straight long parallel holes, can be seen as a micro-channel device. Photons travel along the direction parallel to wall of the channels can pass through the micro-channels; while the photons travel in other directions will be absorbed by the walls of the micro-channels.

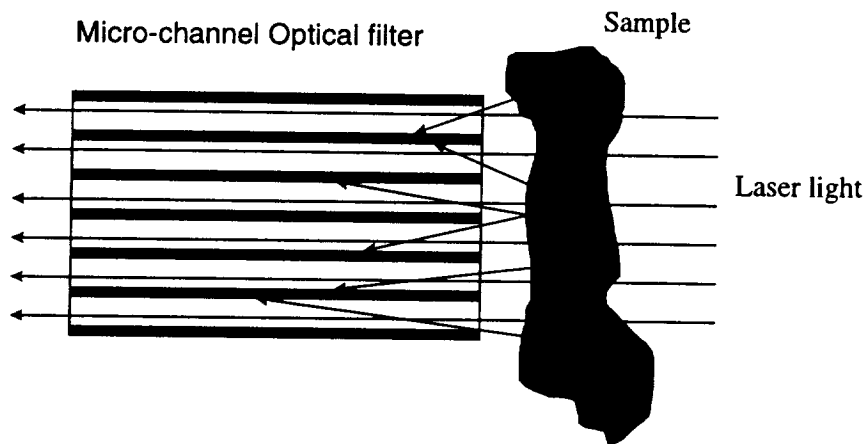


Fig. 1 Only unscattered light can pass through, while the scattered light will be absorbed by the walls of the long channels.

Later on, the concept of "microscope-on-a-chip using micro-channel and solid state image sensors" was invented at JPL⁽²⁾. Since the micro-channel filter can generate an one-to-one mapping from the sample to the end of the micro-channels. If a solid state detector is placed on the other end of the micro-channel filter, and if the pixels of the detector matches the openings of the micro-channel filter, then there will be a one-on-one mapping from the sample to the detector pixels. Fig 2 shows the geometry of the microscope-on-chip using micro-channel and solid image sensors. A beam of collimated light shines on a sample. The sample is rather thin, enough light can pass through the sample. The walls of the micro-channel device are parallel to the incident beam. When the sample is put close enough to the micro-channel device, the absorptive walls of the micro-channel device will absorb the scattered light generated by the sample, and generated an one-to-one mapping from sample to pixel to the image sensor. The index matching liquid, which has almost the same optical index with the sample, is used to reduce the surface scattering.

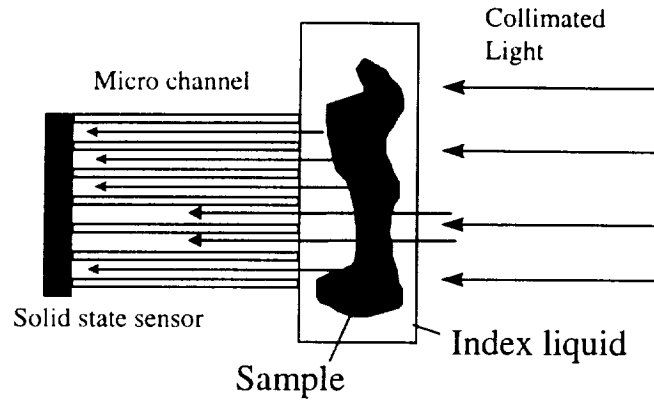


Fig. 2 The walls of micro channels are absorptive, only unscattered light can reach the pixels of solid state image sensor to generate an one-on-one mapping.

The first prototype of microscope-on-chip was built in 1998. It used a commercial CCD camera board as the solid state imager. The camera has 768X494 pixels with each pixel has a size of $6.25 \times 7.28 \mu$. The micro-channel device was a dark glass plate has hexagonal holes made by Collimated Holes Inc., the holes have a 20μ pitch with 50% opening area.

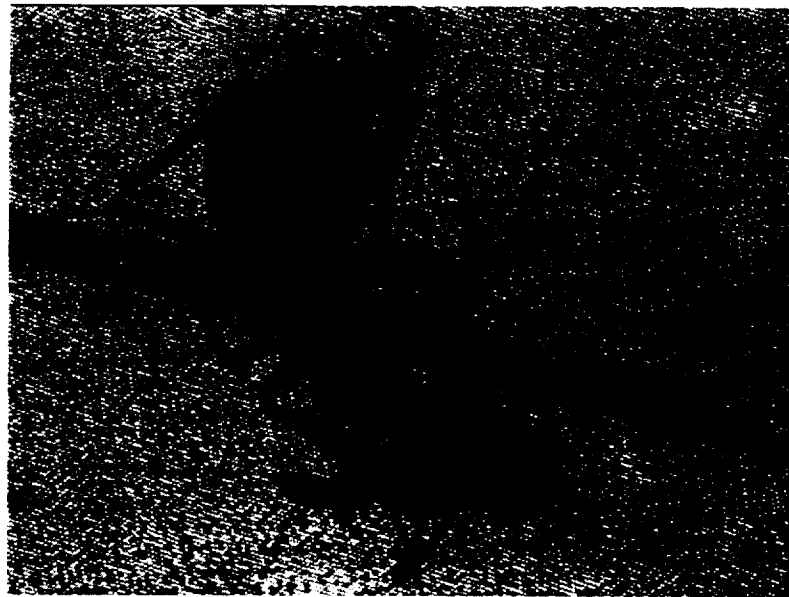


Fig. 3 Image of an ant taken by microscope-on-chip.

The actually prototype instrument is shown in Fig. 4. It has a size about 3cm x3cm x 4cm, and a weight less than 100g.



Fig. 4. Photo of first prototype.

The instrument reported here is microscope-on-chip. With some modification, it can also function in a reflective mode, which is more desirable for NASA's in-situ explore missions. A reflective microscope-on-chip is now under development at JPL.

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