Building ultra-compact laser projectors

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Tiny lasers and a micromechanical light deflector enable miniaturized laser projection systems that could soon be incorporated into portable devices.

Presentation of data of any kind, including photos and movies, will be possible in the near future using mobile devices. This coincides with the availability of electronic displays that offer dramatically increased image quality. Since customers are habituated to the quality presented by large screens, this imposes a technical conflict for manufacturers of mobile devices: the display area is too small to present data appropriately. Flexible displays are one approach to solve this problem, however, it might be a long time until they are commercially available. Projection displays, which are so small that they can be incorporated into mobile devices (see Figure 1), are a different way to overcome this limitation.

Today’s commercially-available projection systems are based on either liquid crystal displays (LCDs) or Texas Instruments’ ‘digital light processing’ (DLP) technology. But optical design limits the miniaturization possible with either type of device. This drawback can be overcome by using lasers as light sources and micro-optical-electrical-mechanical systems (MOEMS), which are much smaller than LCDs or DLPs, for image generation. Both key components are available now. In the meantime, several laser companies offer suitable laser diodes at least at prototype stage, including green lasers, and Fraunhofer IPMS has developed a highly-miniaturized 2D resonant scanning mirror that can be used as a miniaturized deflection unit.

Laser projection systems

Projection systems based on DLP and LCDs project the image in its entirety at the same moment. In contrast to this, the laser projection system described here uses the ‘flying spot’ approach which is similar to the way a traditional TV set with a cathode ray tube (CRT) operates: the image area is scanned by a single laser beam at such a high frequency that every virtual pixel of the image is hit at least once within the time of one image frame and image information is generated by modulating the laser beam, which is deflected by the scanning mirror. By strictly synchronizing both the driving of the mirror and the modulation of the lasers, the impression of a stable image can be generated.

Continued on next page
System realization
A key element of the miniaturized projection module is the 2D micro scanning mirror (see Figure 2). It uses a central mirror plate that is suspended in a deflectable frame by two torsional springs. The remaining region of the circumference of the mirror plate is equipped with comb electrodes for exciting movement. The deflectable frame is suspended to a fixed frame electrode by two additional torsional springs perpendicular to the first pair which results in a 2D deflection of light. Therefore, arbitrary Lissajous figures can be projected by the mirror as necessary. The actuator chip is fabricated with a CMOS-compatible micromachining technology. The devices show a high mechanical robustness, which makes them suitable for mobile applications such as hand-held scanners and projection systems.

The system electronics map the image information in progressive scan mode onto the Lissajous pattern generated by the mirror in real-time. Because of the sinusoidal movement in both axes, brightness correction is required to get a homogeneous illumination. These tasks are implemented inside a field-programmable gate array (FPGA). The resulting digital data for the modulation of the three lasers are converted into analog signals and adjusted to the input voltage range of the lasers and the mirror by operational amplifiers. The electronics support 640 × 480 pixel images (VGA resolution), eight bits of color depth per pixel and elementary color, and can produce 50 frames each second.3

So far both full-color and monochrome systems have been realized. The red-green-blue (RGB) laser module for full-color projection has a volume of only 10 × 7 × 4cm3 (see Figure 3), which is smaller than the smallest LED projector available commercially right now.4 Of course, the size of the complete system can be significantly smaller if only monochrome projection is required. In this case, the laser source can be integrated into the projection module. An example for a resulting projection module is shown in Figure 4 with overall dimensions of only 17 × 7 × 5mm3. Detailed information about the optical design for the RGB laser system as well as the ultra-compact monochrome module can be found in a paper by Andreas Bräuer and others.5

Conclusion
We have successfully built miniaturized laser projection systems, although further research and development is needed for commercialization. One main topic for further work is the need for a significant increase in the laser power efficiency, especially...
for green lasers. We also need to reduce speckle effects in the projected image. This can be achieved, in principal, by modifying the laser sources to reduce their coherence lengths. Given the broad range of applications for compact laser projection systems it is very likely that solutions for these remaining obstacles will be found shortly and such systems will be introduced to the market soon.

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References