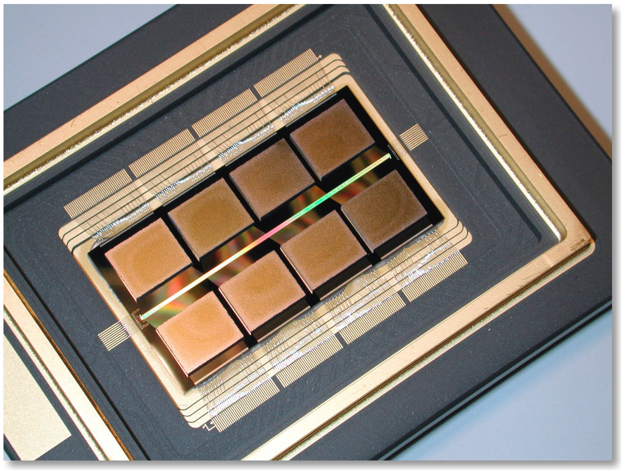
CASE STUDY

An Optical MEMS Device for Projection Displays

Design and manufacture the package, assembly process and test protocols for a Grating Light Valve based 64M display

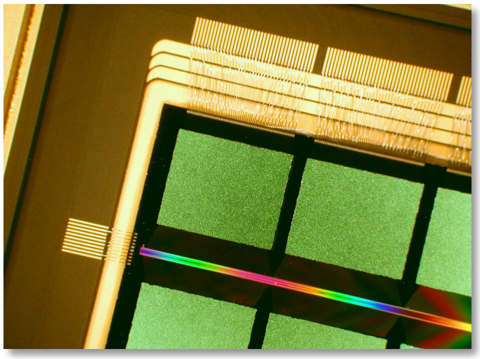


BACKGROUND: Typically displays used in flight simulators and full video planetariums use a synchronized set of conventional projectors to create the video image on very large, non-planar surfaces. These projectors must be perfectly aligned and calibrated so that the "seams" between each display are not visible. This is expensive and difficult to maintain and the light source does not provide a true color gamut.
A MEMS-based Grating Light Valve (GLV) projector system with RGB laser light sources could display the same number of pixels from a single integrated display unit with greater brightness and higher contrast and true color gamut. The team needed someone to design a package and an assembly process and manufacturing the completed device.

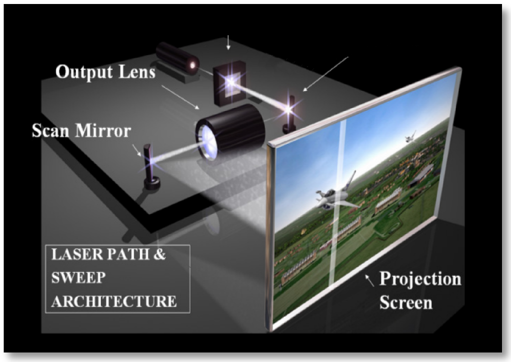
PROJECT DETAILS: A Grating Light Valve is a one-dimensional array of electrostatically actuated MEMS ribbons that can be modulated to diffract or reflect incident light. A single array of ribbons can be modulated fast enough that when combined with a scanning mirror and projection optics that a very large area display can be created. This contrasts with 2D MEMS displays that require an individual MEMS element for each of pixel in the display.

The display consisted of a MEMS die with 4096 individually addressable ribbon sets. Since that number of wirebonds and wirebond pads was somewhat impractical, a package strategy was identified that incorporated a set of eight de-multiplexor die that were flip chip attached to the GLV die. This flip chip subassembly would then be mounted in a custom designed, 460-pin, aluminum nitride ceramic pin grid array package. The die was then wirebonded to the package and the MEMS ribbons released in a XeF_2 process just prior to hermetic sealing.

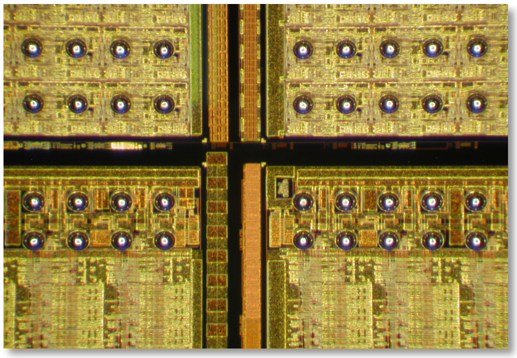
The package needed to not only provide an electrical interface to the external drive circuits, but it also needed to allow laser light to be focused on the ribbon array while dissipating more than 80 watts of power. The custom designed multi-layer, cofired aluminum nitride package was thoroughly modeled prior to fabrication. An underbump metallization and solder balling process was developed for the custom CMOS driver die wafers and a compatible UBM process was developed for the completed MEMS wafers. After the driver die wafers were



A image of the corner of the GLV assembly before release



A schematic of the scanning GLV-based laser display system



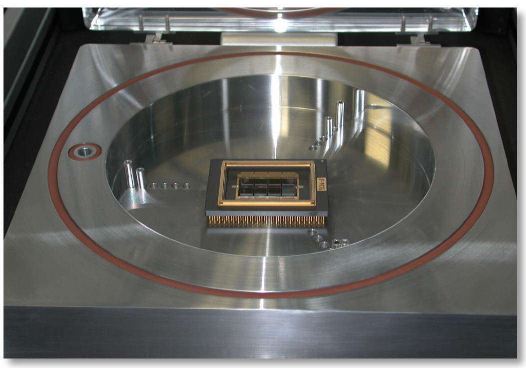
An image of four corners of driver die in a wafer just after solder bumping.

sawn, the die were aligned and reflowed to the corresponding pads on the MEMS GLV die. Over 4600 solder flip chip joints were needed for each device to connect the 8 driver die to the MEMS die. This sub assembly was then mounted into the AlN PGA with a custom formulated, low modulus, high thermal conductivity die attach material. The GLV die were then wirebonded using a room-temperature Al wedge bonding process.

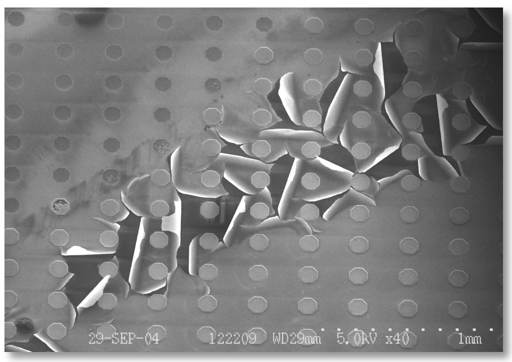
As one of the last steps in the assembly, the entire packaged component was placed in a custom modified XeF2 chamber so that the GLV ribbons could be released. The XeF2 release process was particularly well suited for this device since poly-Si sacrificial layer would be selectively removed relative to the Al-coated Si3N4. While this is theoretically the case, the wide range of materials in the XeF2 resulting in undesired interactions that damaged the thin films and the extremely sensitive reflective surface of the GLV ribbon array. Extensive analysis and a set of complex designed experiments were undertaken to understand the material interactions to find a manufacturable set of release process parameters.

A custom optical window was also developed incorporating anti-reflective coatings and special low-birefringence glass. This window was metalized and solder sealed into a custom Kovar lid that was designed for to be seam sealed to the Kovar frame on the AlN package. Optical, thermal and mechanical modeling validated the design of the package and assembly process.

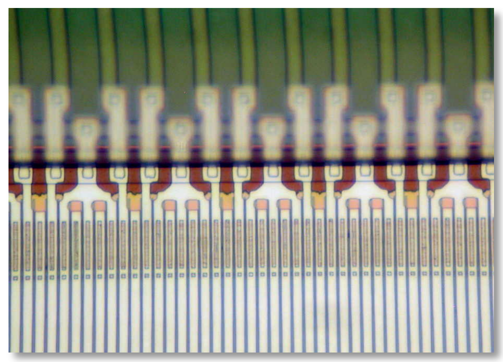
Optical test equipment was developed to test the final devices before incorporation into the display. A set of life burn-in and tests was also developed based on real-life use conditions. Three qualified devices were built into each water-cooled display system which was thoroughly tested prior to field installation



The wirebonded GLV subassembly in the XeF2 release chamber

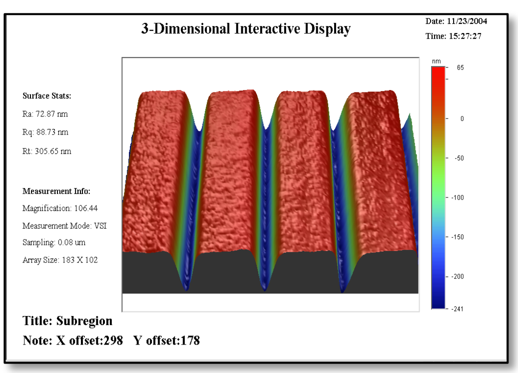


An SEM image of thin film delamination due to interaction with the XeF2 release process.

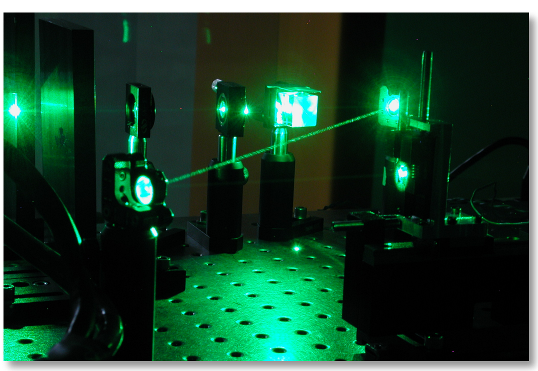


A magnified view of the end of the GLV ribbons after they have been released.

RESULT: The highest pixel count laser display ever made incorporating MEMS display components was developed, package and tested. A number It was successfully incorporated into laser-based projection systems that were installed in locations around the world.



An AFM image of the texture on the optical surface of the ribbon array after release.



The laser test bench used to evaluate completed GLV display divices.

Three GLV devices in a projector as they are being illuminated by the RGB lasers