Subproject A1: “Design of micromechanical components”

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The goal of the subproject A1 is to design micromechanical components that are used within the SFB 379 and to predict their behaviour. This work comprises the following topics:

- Development of design algorithms and tools to capture the specific behaviour of array structures (coupled electromechanical and fluidmechanical fields, interactions between array cells, warping of thin plates caused by thermomechanical and intrinsic stress)
- Modelling and simulation of new micromechanical components used by other subprojects
- Fracture strength of in-plane parallel spring arrays etched from silicon
- Design of new shape elements needed for mechanical and optical applications

Modelling and Simulations

Micromechanical components usually consist of almost rigid bodies (comb drives, seismic mass), which are attached by flexible structures (beams, membranes, plates) to a frame. Nevertheless the remaining deformation state of the moving body, often called shuttle mass, is an essential design quantity since it influences the performance of most MEMS. For instance plate warping of micromirror actuators is responsible for the optical quality of display systems, or warp of comb drive systems may limit the total operating range. Movable microstructures are necessary to transform physical quantities into electrical signals (sensor mode) or vice versa, to drive parts of the structure to a desired position (actuator mode). In both cases accompanying fields are obligatory to transfer energy between different physical domains and must be considered in appropriate models at once. MEMS’s design is complicated by the fact that different physical phenomena are acting on the same part of a structure with strong interactions to each other. Fig. 1 shows a simplified model of a torsion mirror used for high speed laser scanning. Its mirror cell is simultaneously flexure and inertial mass in the mechanical domain, electrode of an electrostatic field in the electric domain, moving wall of a squeezed gap in the fluidic domain (underneath the mirror plate) and heating source in the thermal domain. Furthermore parasitic phenomena like intrinsic film stress, thermal mismatch and mechanical noise caused by air molecule collisions should call our attention. The component designer must have access to sophisticated design tools and a full understanding of all involved physical disciplines, in numerical mathematics, computer science and microtechnologies to obtain a proper layout. Mostly this turns out to be a big challenge. Those effects are considered in the physical domain by coupled partial differential equations within the finite element toll ANSYS. As a second method, ordinary differential equations are used to describe the component at a higher abstraction level within MATLAB, OrCAD-PSPICE or VHDL-AMS.

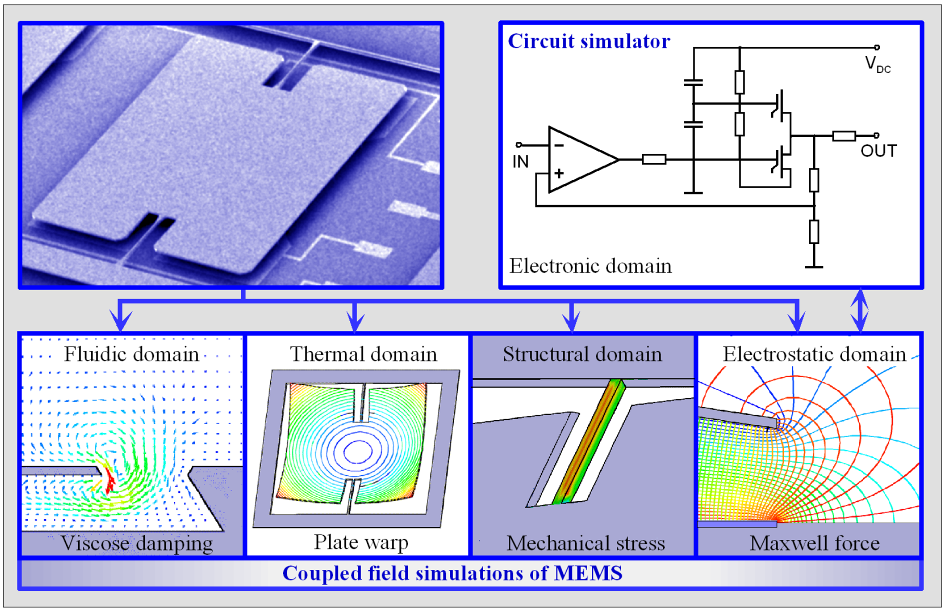

Fig. 1: Influence of different physical domains on the mechanical behaviour of micromirrors

Silicon solid hinge guide with a stroke up to ± 5 mm

Silicon is a suitable material for flexural hinges and similar spring elements. Especially its high elastic deformability in connection with the high bending fracture strength at small strained volumes makes it possible to fabricate these elements.

To demonstrate the functionality of a solid hinge guide of Si a demonstrator was mounted out of available spring arrays with a spring height of 30 µm (see ZfM Annual Report 2002), see fig. 2. For this two arrays were separated by laser. The frames of each two halves and one complete array were connected with a stiff Si beam. The links of the half arrays were glued onto spacers and then on the bottom glass plate. The thickness of the spacers were chosen in such a way, that a strong deflection in transverse direction leads to a striking at the glass plate and not to the break of the array. The fixing of the links of the middle arrays was done with spacers at a thin upper glass plate, whose thickness was choosen as thin as possible to minimize the load capacity in transverse direction.

The basis of this construction built measurements of the transverse stiffness, fig. 3, which were performed inside a self mounted micro force-deformation instrument. Spring arrays and parallel springs were deflected in out-of-plane direction.

The functionality of the solid hinge guide can be shown by moving this upper glass plate with a micro screw. The completely mounted and deflected demonstrator is shown in fig. 4.

First measurements of the straightness (y-deviation from the translation axis x) using an optical microscope show values in the 1 micron region (the optical resolution). This is a remarkable result in view of the simple mounting technique.

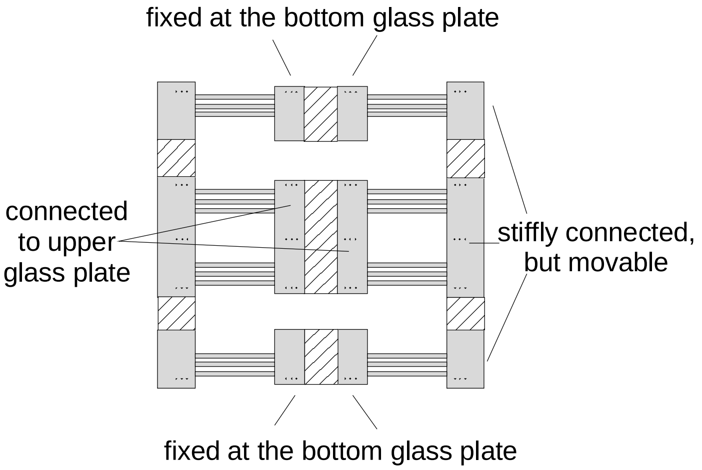

Fig. 2: Sketch illustrating the construction of the demonstrator

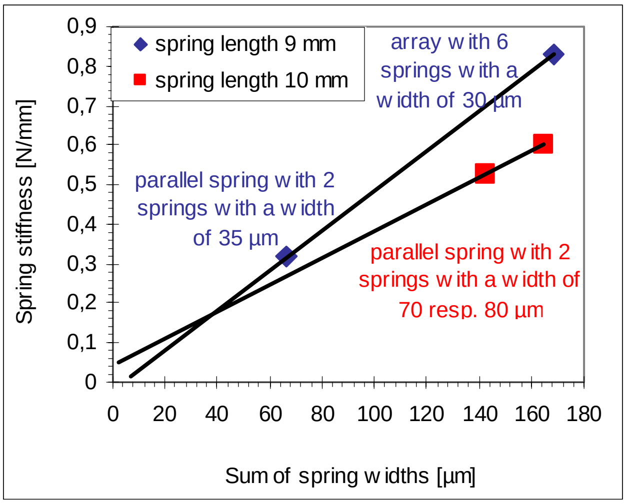

Fig. 3: Stiffnesses in transverse direction

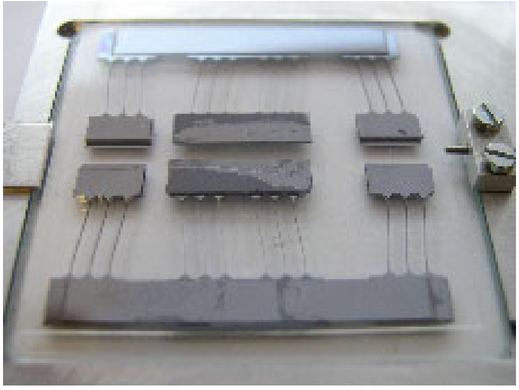

Fig. 4: Demonstrator of a solid hinge guide completely mounted and deflected