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Vertical nanopositioning of heavy mirrors

In spatial working nanomeasuring and nanopositioning machines (NPM) only the usage of laser interferometers offers a sufficient measurement range, resolution and accuracy in the nanometer range. According the measurement principle which fulfills the Abbe principle in all directions the object has to be fixed to a surrounding element carrying the necessary reflective planes. This mirror has to be moved together with the object through the work space relative to the fixed interferometers and has always been hit by the laser beams. Thus long aspired traveling ranges of big working volumes demand huge mirrors which have already maximized structural stiffness for achieving high accuracy of measurement. Because of material requirements such a mirror is associated with big mass that commonly exceeds the weight of the object.
In NPM a structure is needed that allows to drive the heavy components reaching a positioning accuracy and stability in nanometer range. This gives high demands to active and passive design components that characteristics for the aspired accuracy in static and dynamic modes are object of research.

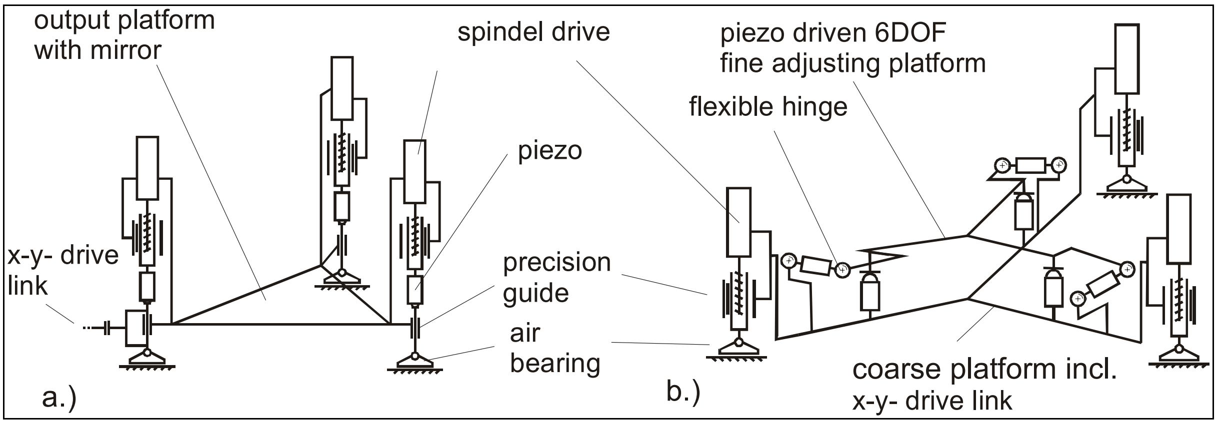

Fig. 1 Testing configuration of nanopositioning z- axis

In the vertical axis of spacious positioning machines the from mass resulting forces have to be supported by active elements also in static modes. Using force actuators, like voice coils, is permanently associated with a high dissipation loss which generates heat spots and disturbing influences on measuring accuracy. Alternatives are passive force accumulators for weight compensation, that are mostly complicated, nonlinear and dependent on working point or the usage of travel generating actuators such as piezos. A problem is the short stroke of these elements. To reach the necessary traveling range the piezos are connected in series with long travel actuators to generate an active system with a fine and a coarse part. According to demands of nanopositioning machines a prototype of an active vertical- axis was built up that allows the positioning of an approx. ca. 5kg measuring mirror with simultaneous mechanical compensation of the tilt around the horizontal axes (Fig. 1a.)). The traveling range is 20 mm with resolution of final position down to ±5 nm (Fig.2). Typical moving behavior in vertical- direction are is shown in following diagrams with long steps over the whole traveling range and position after small step.

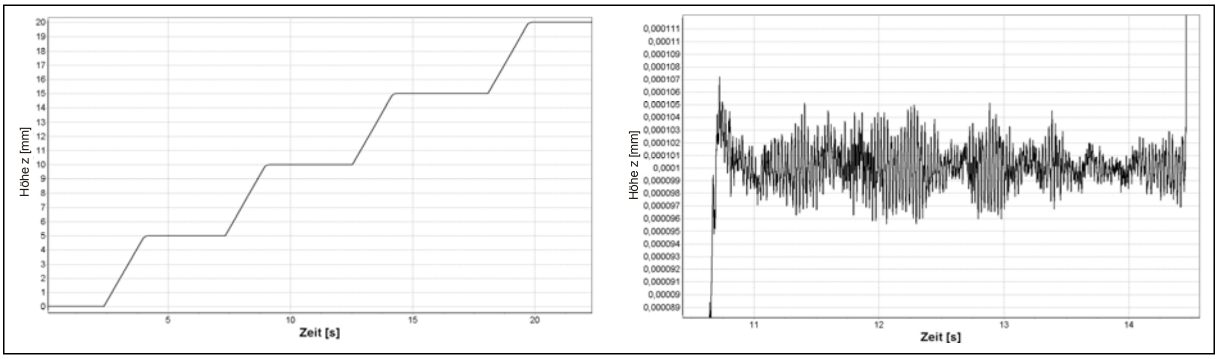

Fig. 2 moving behavior of test configuration (long steps and static state after short step (approx. ±5 nm))

To analyze the dynamic behavior a second test configuration was built up (Fig.1b). By simplier elements and consistent separation of function it is possible to decrease the number of influence parameters an make them assignable to structural parts of the over all system. Further on the design is an upgraded variant. By separation in a coarse and fine module the axis is divided in two parts (Fig.3). The mass of the high dynamic driven output is minimized and only dominated by the weight of the mirror. Thus the dynamic forces could be decreased. A horizontal fine positioning is possible near of the output. The test configuration shows the equal influence of elastic characteristics of joints and “rigid” elements. The perceptions of macro mechanical engineering are only conditionally assignable.

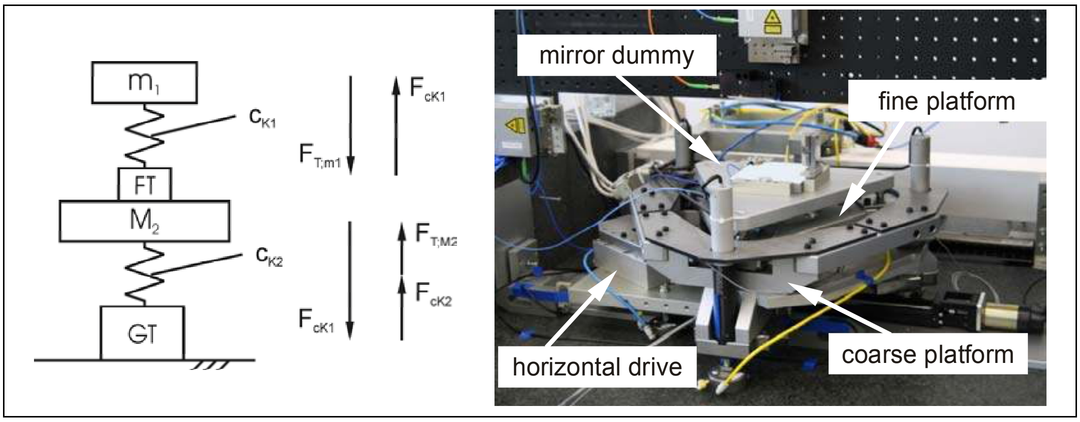

Fig. 3 Configuration for dynamical analysis (basic dyn. principle; technical realization)

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