is focused on the sample/fiducial to generate a back-scatter signal. The focused laser light scatters off the mark and can be detected in transmission or reflection geometries by detecting either forward or back-scattered light respectively. There are one or more photosensitive detectors. The photosensitive device, in response to receiving the scattered light, outputs signals which reveal the dimensional position of each fiducial mark, and hence the dimensional position of each structure. These signals are used in a feedback loop to keep the differential position stable, or to permit the precise scanning of the position between the two structures. The structure is aligned by translating it through the laser beam to generate a calibration curve. There can be an alignment of two or more independent structures relative to each other, or relative to a shift of a known center, or the structures can be raster scanned with respect to each other. The calibration curve can also be attained by moving the laser beam through the structure. The sample's and tip's dimensional positions were controlled via a feedback loop associated with precision positioners, to which the sample, tip, or both are connected. The tip is retracted, replaced and the above process is repeated.

[0024] By aligning the position of an atomic force microscope tip and the sample to a pair of focused laser beams, the tips can be exchanged and the same individual feature can be rapidly reimaged with nanometer-scale registration. The individual tips could be retracted and realigned, which could be useful for cleaning them to remove surface absorbed proteins that could introduce artifacts. Other types of processing are also possible after the tip is removed and before being replaced.

[0025] Different individual tips of the same type have slightly different shapes due to the manufacturing process, which leads to an offset between the optical center of the tip measured by scattering off the front side of the tip and its true mechanical apex. The limit to this technique is expected to be about 1-5 nm, based on the curvature of the tip and any atomic-scale protrusions from the tip that are not centered with respect to the optical axes of the tip. Different style tips and different tilts to the cantilever also have a reproducible offset, which can be quantized and removed.

[0026] Two dimensional registration can also be done by putting a fiducial mark on the back side of the cantilever chip (e.g. at the base of the cantilever) and doing back-scatter detection (BSD) from the atomic force microscope side (e.g. with the lasers not going through the sample). While there is an offset to the mechanical imaging point, time variation in this offset would be small due to its limited distance (3-100 μm) and compatible with general methods for producing and using commercial atomic force microscope tips. This is in contrast to the complexity of the interferometric-spatial-phase imaging atomic force microscope tip sample stabilization process put forward by the MIT work described in Moon, E. E., Kupec, J., Mondol, M. K., Smith, H. I. & Berggren, K. K. *Atomic-force lithography with interferometric tip-to-substrate position metrology*. J. Vac. Sci. Technol. B 25, 2284-2287 (2007), incorporated herein by reference.

[0027] The ability to align the tip in three dimensions with respect to a laser foci also suggests a method to gently and reproducibly bring the tip down to the surface in a controlled manner through an series of alignments of the tip to the laser, followed by movement of the atomic force microscope assembly and a compensated motion of the z-foci of its detection laser (e.g. a movement of a lens).

[0028] The present method can be performed using a wide variety of scanning probe microscope (SPM) tips. The preferred embodiment, which is in no way limiting, is an optically stabilized atomic force microscope (AFM) integrated with a customized inverted optical microscope. Two independently steered laser beams are focused to show diffraction limited spots by a high NA objective lens placed below the sample plane.

[0029] A representative microscope comprises a light source, preferably a laser, for providing coherent light incident on a fiducial mark, a photosensitive device for receiving at least a portion of the light scattered off the fiducial mark and which generates a signal in response to the scattered light received, a precision positioner, which can be moved in accordance with the signals generated by the photosensitive device's reception of scattered light from the fiducial marks, a feedback loop, including a feedback algorithm/processor to provide an output signal that is related to a characteristic of the input signal generated by the photosensitive device and received by the feedback loop, to provide a control signal that controls movement of the precision positioner.

[0030] As shown in FIG. **1**A, one laser beam is focused onto the apex of an atomic force microscope tip, and a second beam onto a fiducial mark engineered into the sample. Back-scattered light from each beam is collected and used to deduce the dimensional position of each object relative to its detection laser focus. The extreme differential pointing stability between the foci (0.02 nm) leads to an optically based reference frame that can stabilize the tip relative to the sample. This local detection of the tip-sample separation (z-tip) is independent of the standard observable, cantilever deflection. In one embodiment, scattering occurs from below. FIG. **1**B illustrates a second embodiment, which can be used with completely opaque samples by engineering a fiducial mark near the base of the cantilever and scattering from above. For purposes of the present invention, the tip region refers to either the tip itself or a fiducial with a fixed dimensional relationship to the tip, for example, with a fixed lateral offset from the tip.

[0031] FIG. **2** illustrates one possible optical layout. Two stabilized diode lasers (SDL) are launched into the system through a single fiber, which improves differential pointing stability. The beams are separated by wavelength for independent steering and focusing, then recombined and sent into the objective.

[0032] The laser beams can be focused with a variety of lenses (e.g., 1.4 NA oil immersion, 0.7 NA air gap). The laser beams can also be of a variety of wavelengths to maximize sensitivity or to penetrate substrates that are optically opaque to visible light (e.g. silicon wafers). The focused laser light scatters off the mark and can be detected in transmission or reflection geometries by detecting either forward or back-scattered light respectively. The laser most preferably has ultra-low noise characteristics which are typically achieved by active feedback, but this method is by no means limiting. The laser light will be scattered off the two or more mechanically independent structures either continuously or within certain predefined intervals to ensure that the separation between the structures does not vary within predefined limits.

[0033] Although the preferred embodiment was implemented in the context of an ultrastable atomic force microscope which uses two laser beams, this tip exchange registration can also be achieved with a single laser equipped with the ability to reproducibly scan over a large area. A single laser