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Using optical sensors with Sin / Cos interpolation in nano-positioning devices.

Due to the nonlinear properties of the piezoceramics, the image obtained during scanning is distorted. The nonlinear properties of piezoceramics should be understood as features of the relationship between the control electric field and the deformation of the piezoceramic actuator, the nonlinearity and ambiguity of this dependence. Usually, the non-linear properties of ceramics are: creep, hysteresis and non-linearity. Also, nonlinear properties include the instability of the sensitivity of piezoceramics.

For a scanner, which is not equipped with sensors, the control voltage for this axis is an indicator of it's position along this axis. Nonlinearity and ambiguity of the dependence of the control voltage-position often leads to significant distortions in the resulting image. To correct the movement along the axes and to determine the position of the translator in space accurately, sensors with different principles actions may be used. It can be optical, inductive, magnetoelectric, capacitive, etc.

The scanning stage Ratis uses optical sensors. The principle of operation of such sensors is shown in Figures 1, 2. The displacement sensor (Fig. 2) consists of an

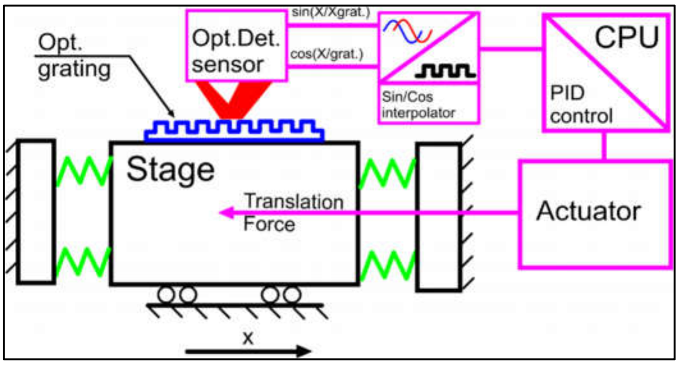

Fig. 1. Block diagram of the feedback device based on optical encoders.

optical ruler, a period of 10 µm or 20 µm, a radiation source of a red light diode, and a selective radiation detector outputting signals shifted in phase by 90 degrees:

A(x)=A0×sin(X/Xgrat)

B(x)=B0×cos(X/Xgrat)

X – translation,

Xgrat – optical grating period.

These signals in analog form are processed by a specialized microchip with built-in sin/cos interpolator, producing the angle calculation as arctg (A/B). Thus, the movement is reduced to calculating the angle, then the chip converts the angle into pulses, which are formed when the minimum detectable angle α of rotation is exceeded.

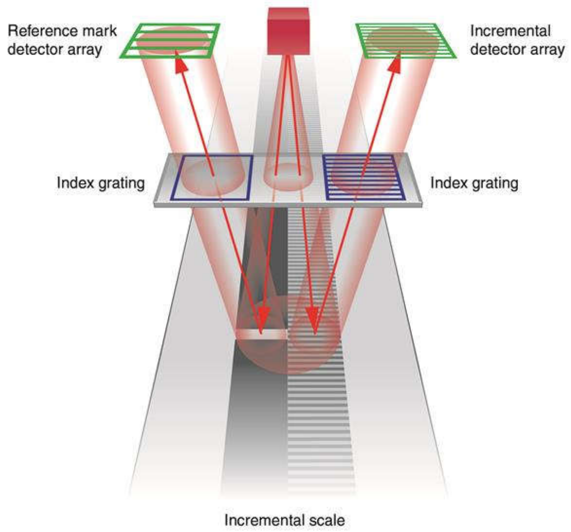

Fig. 2 The device of the optical position sensor.

Then the movement is calculated as:
X =Sn× α× Xgrat, Sn- Sum of pulses from a specialized counter.

Optical sensors produce displacement calculations along a special plate, on which lines are plotted with a specified period. Lines are caused by interference of waves with given lengths, which leads to high accuracy of the length of the period of these divisions. When measuring a distance, the number of periods or the part of the period that the sensor has passed is calculated. Since all the phenomena in this sensor are correlated to the wavelengths, the accuracy of the measurements is quite high. In addition, optical sensors are linear, which significantly increases the efficiency of their operation. The use of optical sensors has a number of undeniable advantages to capacitive sensors, which are common in scanning probe microscopy and devices: all absolute linear calibration over the entire displacement field, in contrast to capacitive sensors having a pronounced nonlinearity described by the 1 / x dependence, which leads to a strong non-uniformity of feedback adjustment, and accuracy by the whole traveling field. Capacitive sensors exhibit instability with a small change of the initial distance between plates, which leads to the need for re-calibration, this can be caused by changes in external conditions, such as temperature, and mechanically. Optical sensors based on Sin / Cos interpolation has notof all these drawbacks. In the course of the measurements, the following characteristics were obtained:

- Accuracy of movement: <1 nm
- Measurement speed: 200 kHz
- Nonlinearity: <0.1%

Fig. 3 Scanning piezoelectric Ratis XYZ_H using optical encoders.