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Testing of a New Focus Picomotor[2] in the Pressure Range of 0.1-10 torr

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ABSTRACT: We have measured the resolution of a model 8302 Picomotor in the pressure range between 0.1 and 10 torr in air using an interferometer. We have not experienced any problem due to arcing. The resolution was better than 28 nm/step, independent of pressure.

1. INTRODUCTION

The light between the telescopes and the Beam Combining Laboratory will be guided through dozens of optical elements along $\sim 30 - 150$ m paths. Some optical elements in these paths have to be aligned with an accuracy of one arcsecond. We planned to utilize New Focus Picomotors for fine these adjustments. Picomotors are built upon an elegant invention utilizing a piezoelectric transducer to turn a screw. This technology gives us the necessary resolution.

A part of the light beam will travel in vacuum (≈ 1 torr) to minimize turbulence effects due to small temperature variations along the path. In the pressure range of $0.01 - 10$ torr, which is often referred as the "corona discharge region," the air conductance is higher than both below and above this pressure range. The increased air conductance can result in arcing. Although the piezo used in the Picomotor is a relatively low-voltage device that should not cause arcing, we wanted to investigate whether this was indeed the case.

2. THE EXPERIMENTAL SETUP

The screw in the Picomotor moves less than 30 nm/step. To measure such a small motion and to test whether it skips steps due to arcing, we built the small interferometer shown in Figure 1.

The light from a laser diode (λ=670 nm) was focused by a small lens onto a 30 μm pinhole. In order to simplify the design, we did not use a collimator after the pinhole. The light from the pinhole was divided by a beam splitter prism. The two beams were reflected from two small flat mirrors and combined again by the prism and detected by a photodiode. One of

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[2]Picomotor is a trademark of New Focus, Inc. 2630 Walsh Ave, Santa Clara, CA 95051-0905.

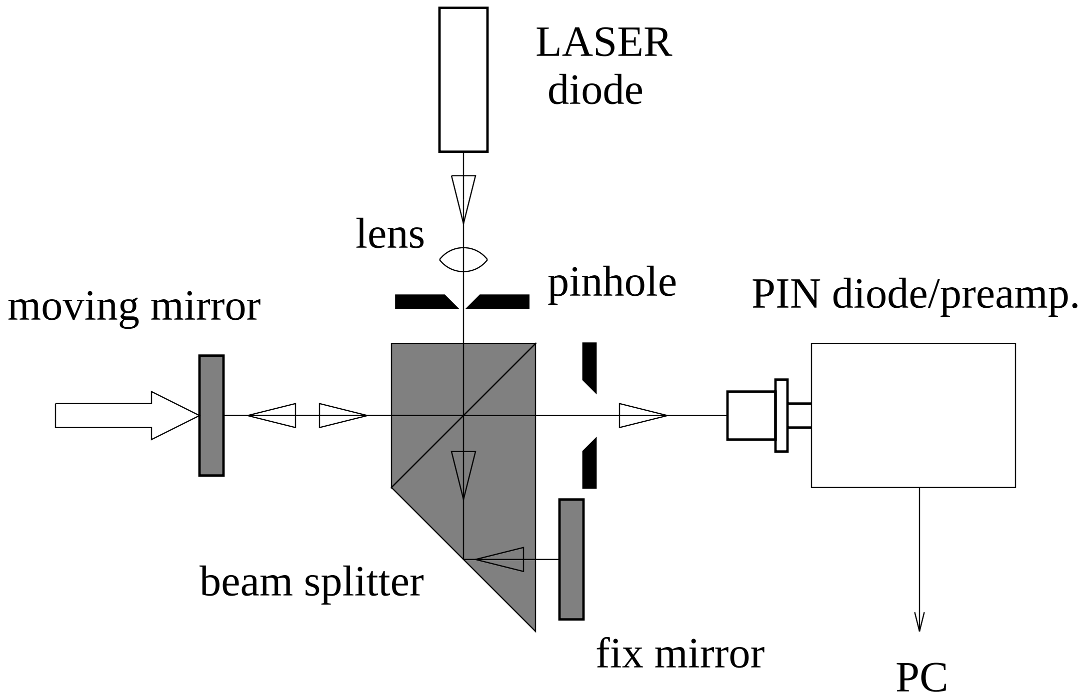

FIGURE 1. The experimental setup of the interferometer used to test the Picomotor.

the mirrors was fixed and the other was moved forward by the Picomotor. The frame of the interferometer was milled from a single piece of aluminum alloy and is shown in Figure 2.

Both mirrors are bonded to polished steel rods in such a way that small angular adjustments were possible. One rod with the moving mirror slides on four hard steel balls as the screw of the Picomotor pushes it forward. This rod was preloaded against the guide ball bearings by a strong magnet. The setup, which is shown in Figure 3, did not allow us to pull the mirror backwards. Therefore, the motor was tested only in one direction. The other mirror was permanently mounted into the aluminum frame.

The interference pattern is a series of concentric rings aligned by adjusting the mirrors so that the zero order falls on the detector (see Figure 4). As the mirror is pushed by the Picomotor, the intensity of the zero order varies according to the difference between the two path lengths. This variation is detected by a PIN diode whose output is digitized and recorded by a computer.

The interferometer turned out to be very stable and insensitive to vibrations. An accidental dropping from about 2-inches height onto a steel optical table did not misalign the instrument. The overall size of the interferometer is only $3\times6\times1.5$ inches in order to fit into a small vacuum chamber built for this experiment and shown in Figure 5. Pressure is measured by digitizing the output of a Pirani vacuum gauge.

3. MEASUREMENTS

After an initial alignment, the interferometer with the Picomotor and the detector was placed in the vacuum chamber. The chamber was pumped down to 0.03 torr. The pressure

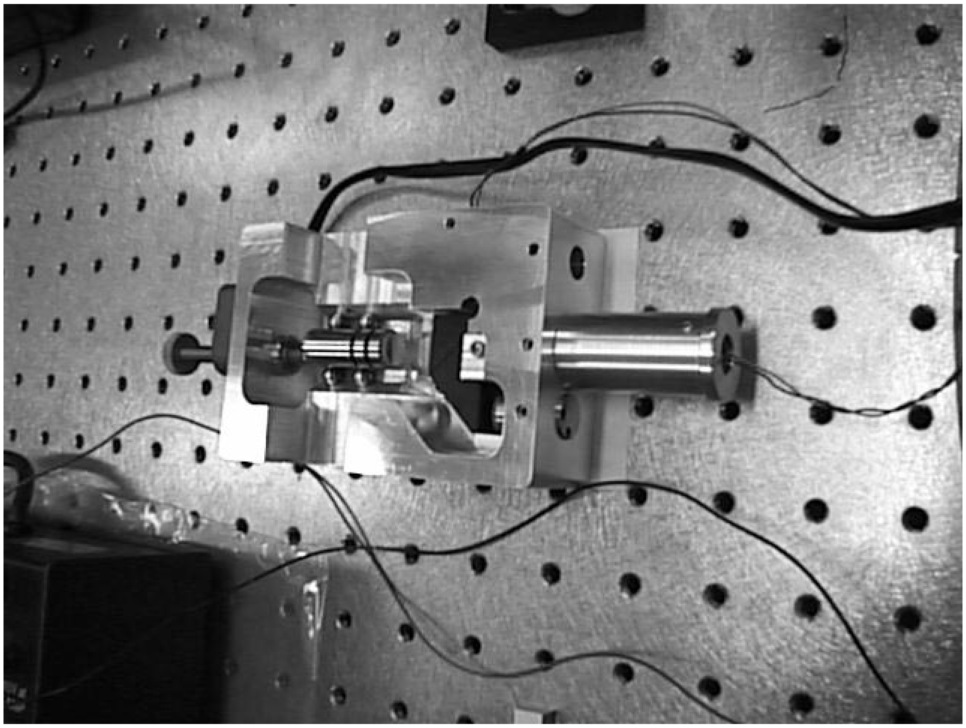

FIGURE 2. The frame of the interferometer was milled from a single piece of aluminum alloy.

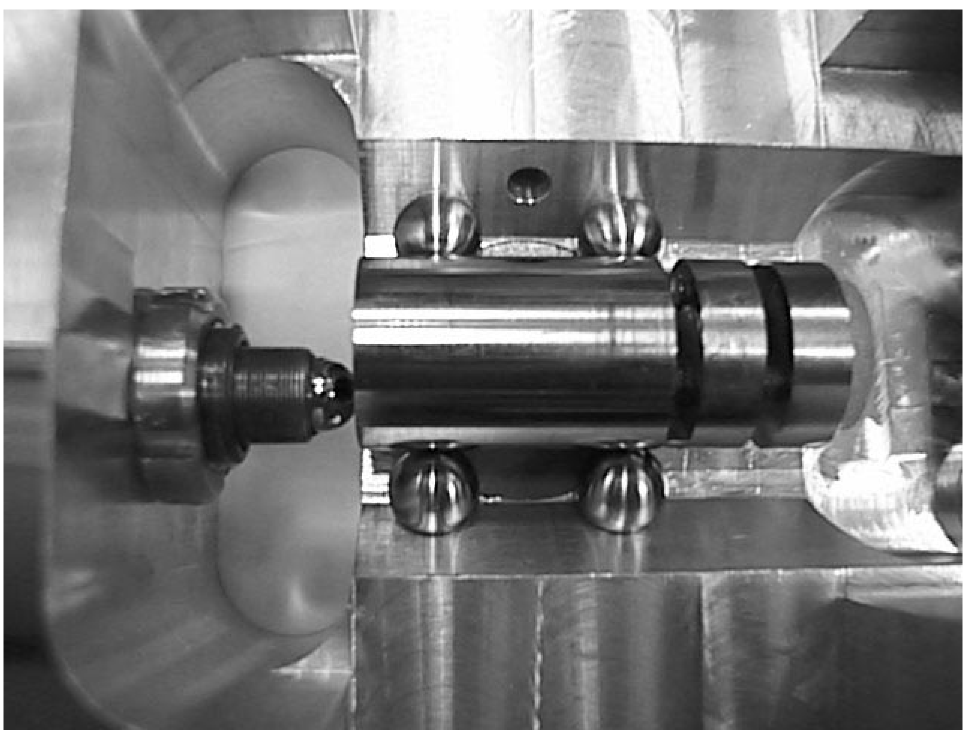

FIGURE 3. The moving mirror slides against on four ball bearings. The polished steel rod was pulled against the bearings by a magnet.

FIGURE 4. Simulated interference pattern in the plane of the diode.

slowly increased due to out-gassing of the chamber wall, but the change was so slow that we consider the environment to be quasi-stationary during a measurement. In order to test the motor for an extended duration, we wrote a program which moved the motor one step forward, waited for 10 ms, read the pressure and then read the output of the PIN diode 100 times. The mean and variance of the 100 measurements were stored on disk. This sequence was repeated approximately 150,000 times. If the motor performed well (no skipping of steps) the intensity on the diode should follow a smooth sine curve. Any missing step or erroneous behavior of the Picomotor would result in some disturbance in the light curve. Figure 6 shows the results of a typical run. The output appears close to the ideal sine curve. On closer inspection, however, it appears that there were at least two major Fourier components present in the output signal with slightly different frequencies. Indeed, the Fourier transform of the output signal shown in Figure 7 clearly shows many slightly different components.

The origin of this intricate spectrum is unclear. The length of individual steps is a function of the axial load on the screw. The load is likely to vary due to imperfections on the sliding mirror support. Also, there is always some dirt or lubricant on the screw which changes the necessary torque to rotate the motor with a given angle. Nevertheless, the steps are surprisingly uniform. All the major periods are between 25 nm/step and 28 nm/step which is less than 6% non-uniformity. We did not find signs of missing a step entirely or of arcing. The Picomotor was fully operational under these circumstances and thus promises performance adequate to our needs.

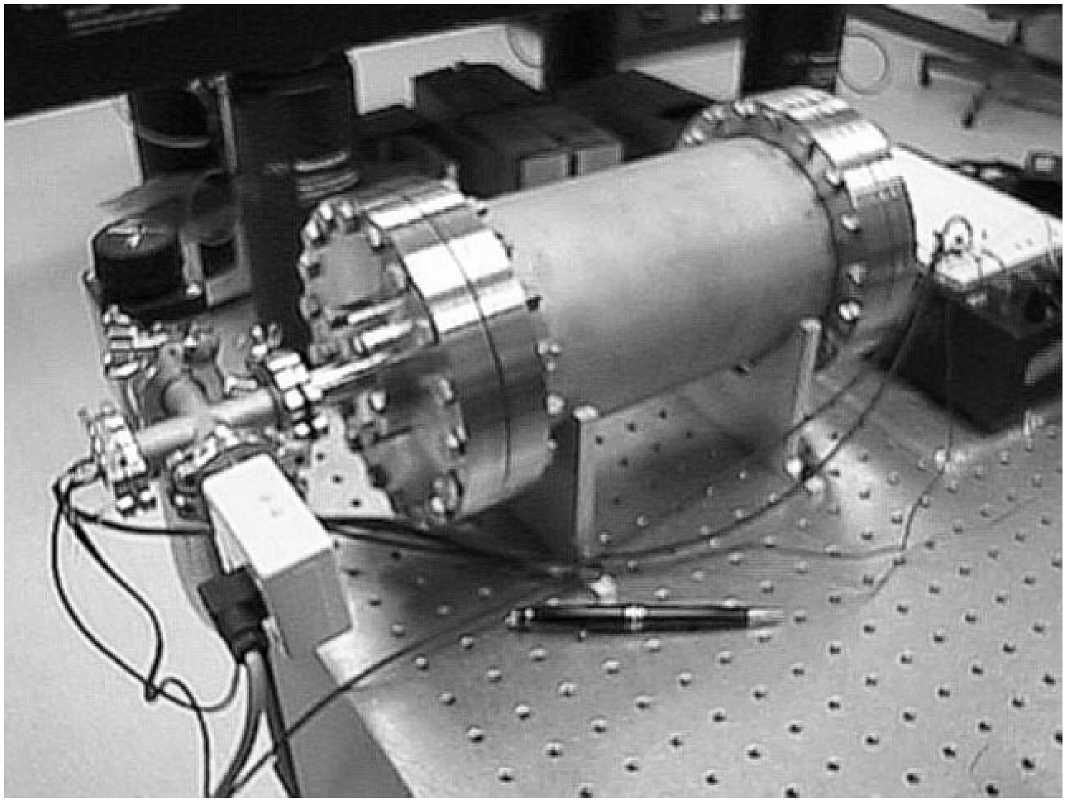

FIGURE 5. The vacuum chamber, valve and pressure gauge.

4. CONCLUSION

In this experiment we tested the operation of a standard Picomotor at low (0.1-10 torr) pressure. We were interested to see whether arcing was a problem in this pressure range. The experiment has shown that a standard 8302 Picomotor performs flawlessly in this pressure range as well as at normal atmospheric pressure. The result makes us confident that these motors will perform well in our vacuum system.

We would like to thank Dr. Bob Shine and Mr. Tracy Qubo for providing us a Picomotor and controller free of charge to perform this experiment.

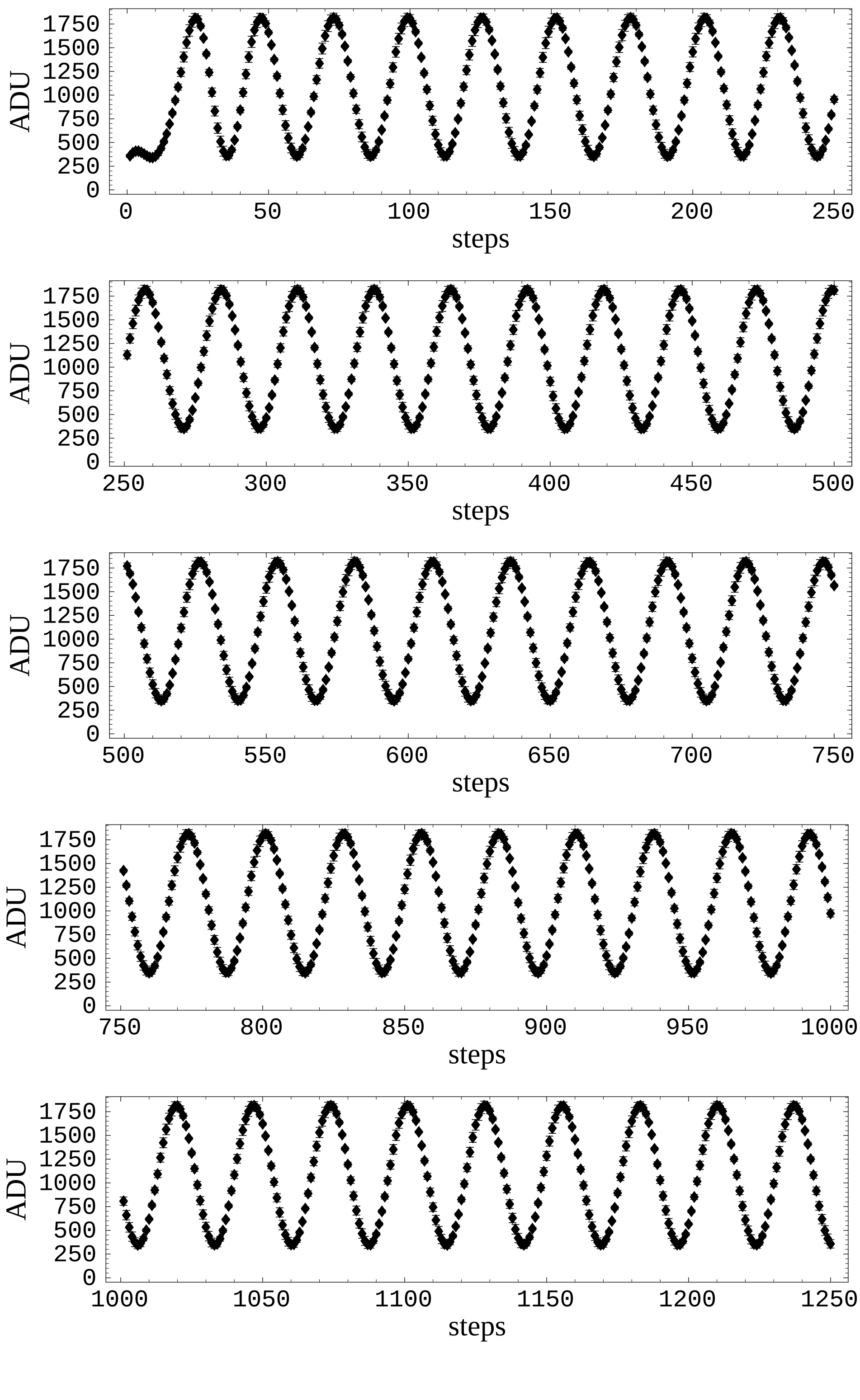

FIGURE 6. A typical output of the PIN diode as a function of steps. The pressure was 0.7 torr. The deviation from a sine curve at the beginning of the plot is due to flexure in both the interferometer and the motor.

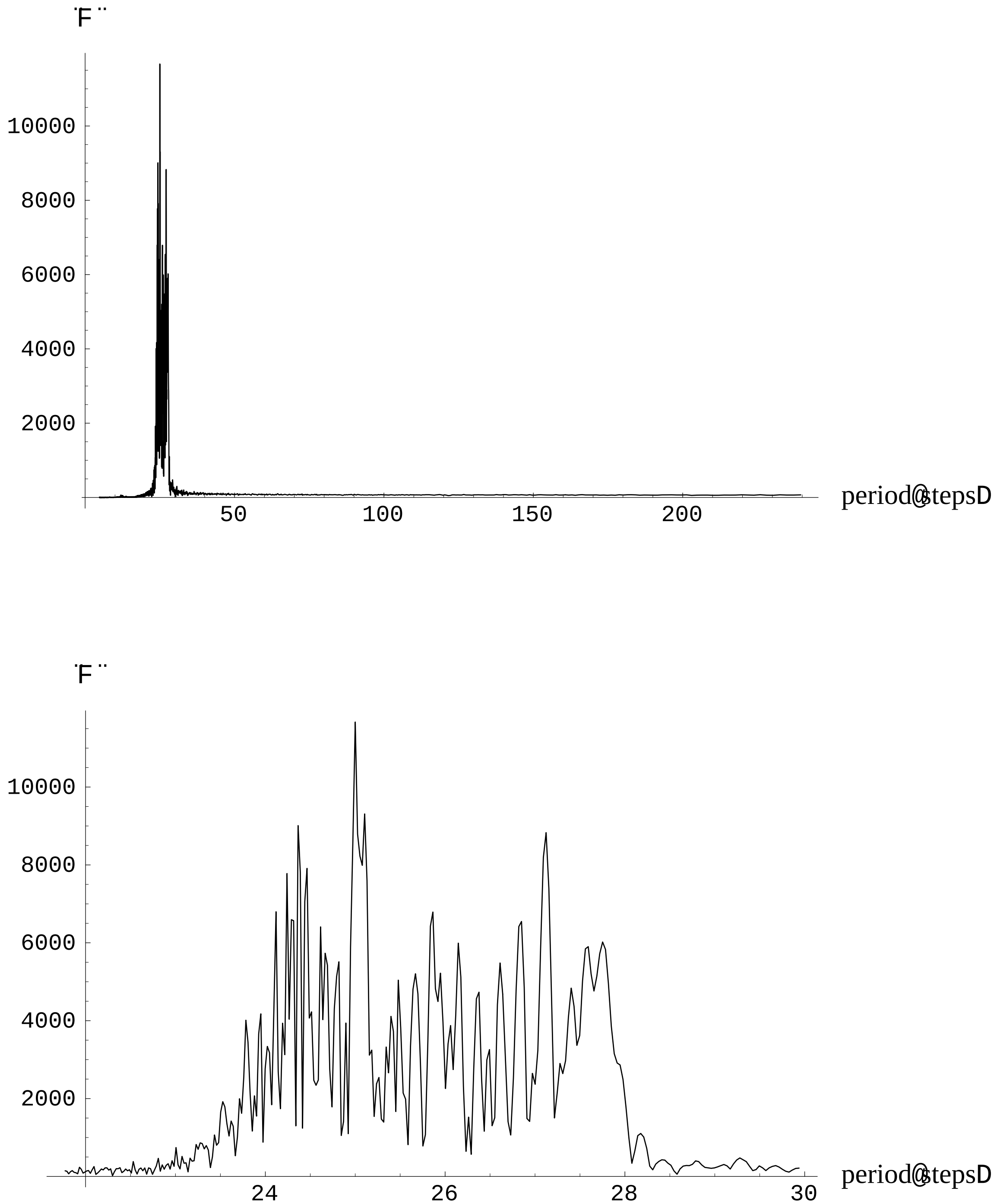

FIGURE 7. The absolute value of the Fourier spectrum of the diode output computed from 24,000 points. The motor resolution is better than 30 nm/step.