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Stability of Beam Position Under Vibration between PC and APC Fiber

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1 Introduction

We have observed that the motion on a fiber optic with PC (straight cut) connector causes the change of the position of the outgoing beam. We suspect that the flat cut may generate a reflection of light back to the laser and cause it to mode jump on a non TEM 0,0 mode, thus changing the fraction of light injected in the core and in the cladding. The APC (angle cut) connector reduces the effect of the reflection, thus has more stable output beam.

2 Experiment Setup

The laser source is a Thorlabs LPS-675 FC pigtail laser. It has a PC connector for the output, which is connected to a test fiber, then the collimator. Two test fibers are PC-APC fiber and PC-PC fiber. Matching collimators for PC and APC with same nominal focal length are connected to the other end of the fibers. To check the sensitivity of the fiber under vibrations, a 250mm loud speaker is used to shake a part of the fiber at different frequencies. A QPD is 2.0 m away from the collimator. Voltage outputs from four quadrants are recorded individually at 1kHz. First, the spot is centered on QPD, then the experiment is repeated with the beam at +150 microns on x and y directions. Total voltage (Vsum) and normalized horizontal and vertical positions of the beam are calculated by kaleidagraph software.

Table 1: Parameters of the beam in the experiment.

	APC	PC
Vsum [Volt]	6.5	6.5
Calibration [mV/um]	20.16	20.38
Spot Diameter [um]	744 +/- 2	741+/-2

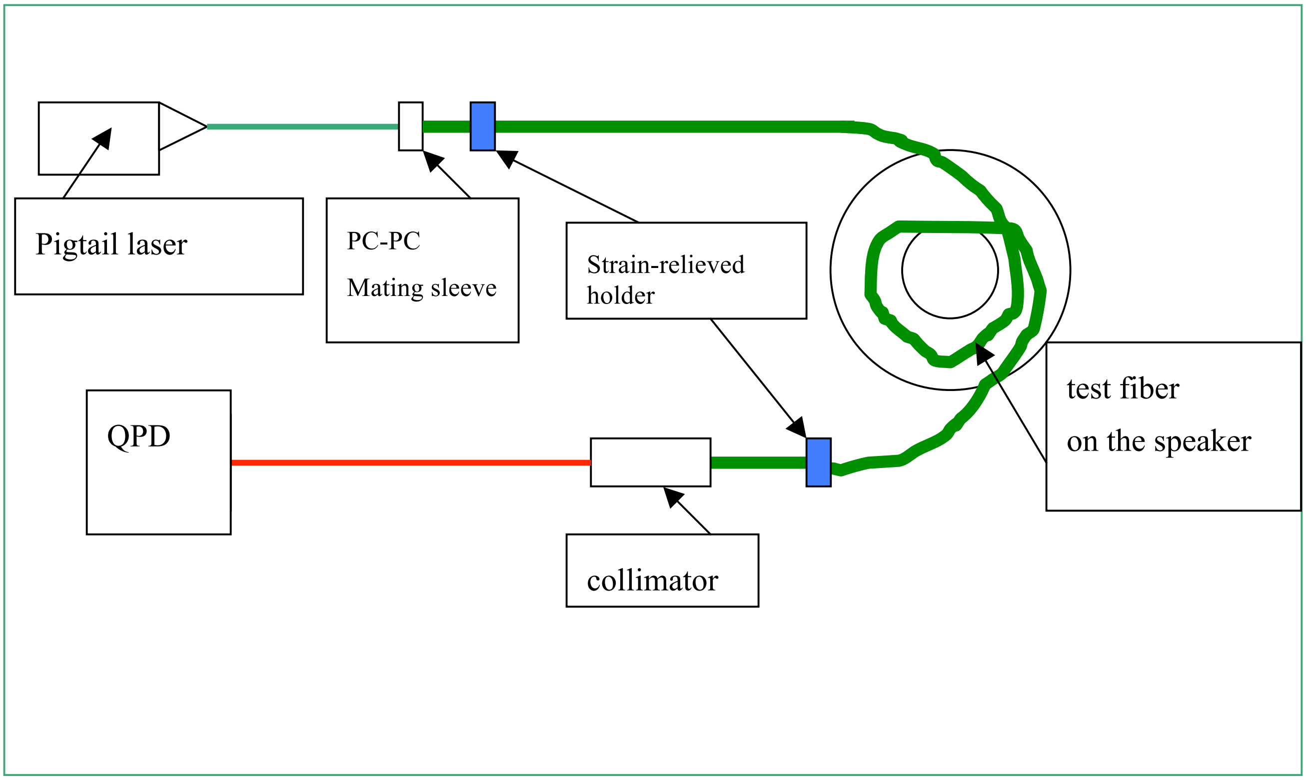


FIGURE 1: experiment setup. A part of the test fiber is put on the loudspeaker. Both ends of the fibers are strain relieved to make sure that there will be no bending at the connectors and collimators due to the shake. Then the data is recorded. The fiber is kept still (the speaker is off), and then shaken at 40Hz and 20Hz, and back to no shake. Each movement lasts 20 seconds.

3 Test on PC fiber

Shaking of the fiber generates strong power fluctuations, but little effect on the position readout when the beam is centered on the QPD. The power fluctuations induce large position errors as soon as the beam leaves the center of the QPD

3.1 Beam centered on the quadrant photodiode crosshair

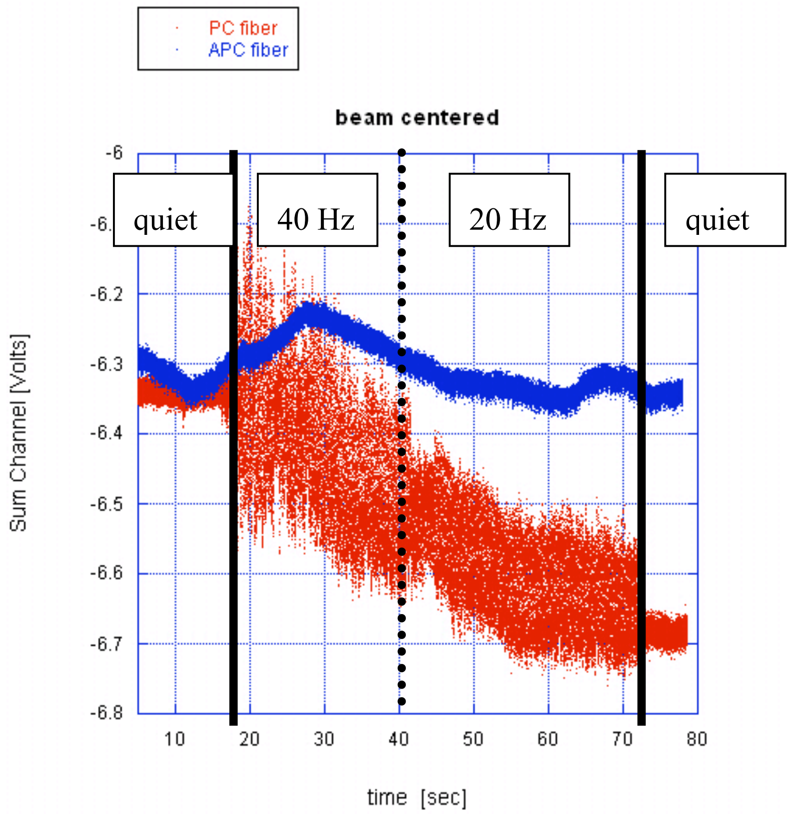


FIGURE 2 Vsum (total power of the beam) [Volts] vs time from data between APC and PC fibers. There is no shake during t < 20s and t >70 s. The fiber is shaken at 40 Hz between 20s – 40s, and 20 Hz between 40s – 70s.

If we compare fluctuations in x and y directions between APC and PC fiber, no significant difference is observed on both fibers. And no clear response to the speaker. In both cases there seems to be a fluctuation unassociated to the shake.

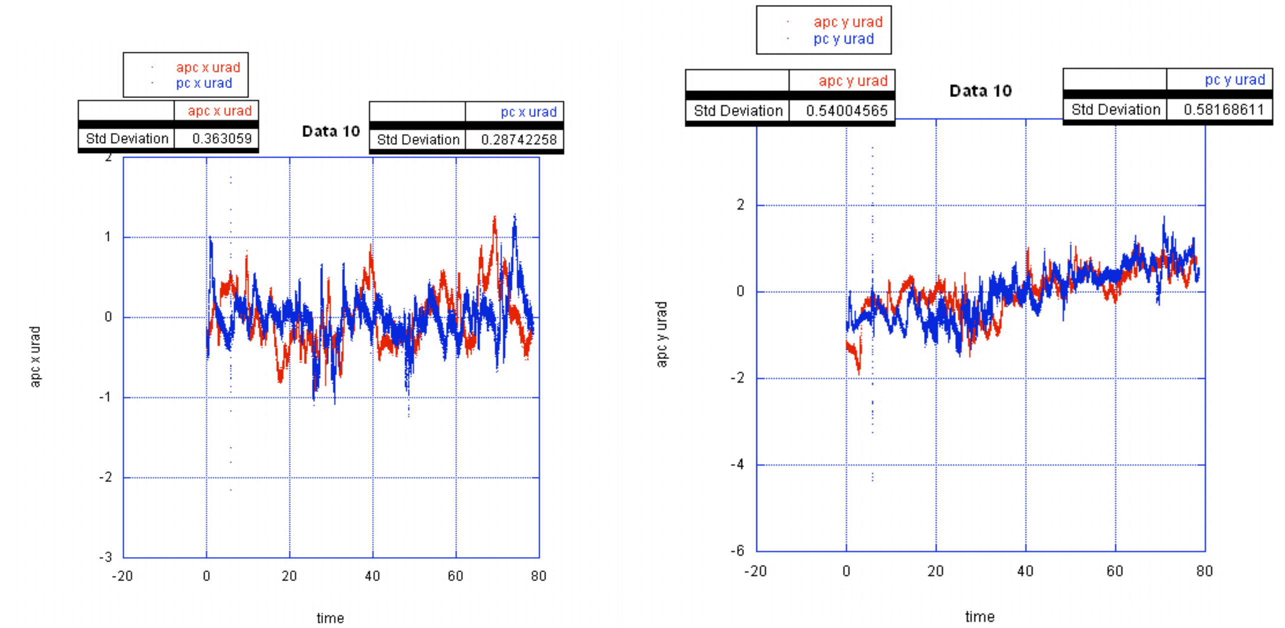


FIGURE 3 Left plot, comparison on normalized X (urad) between APC and PC.

Right plot, comparison on normalized Y (urad) between APC and PC. The drift may be stand drift under the weight of the fiber, the fluctuation due to air motion. All to be further investigated.

3.2 Beam off center

The same measurement is repeated, but the beam is moved to (+1.5V, +1.5V) (about 75 microns on x and y away from the center, the beam spot size ~ 750 microns, Vsum = 4 Volts.) There is no shake from t<30s and t>70s. A 20 Hz shake happens between 30s <t < 70s.

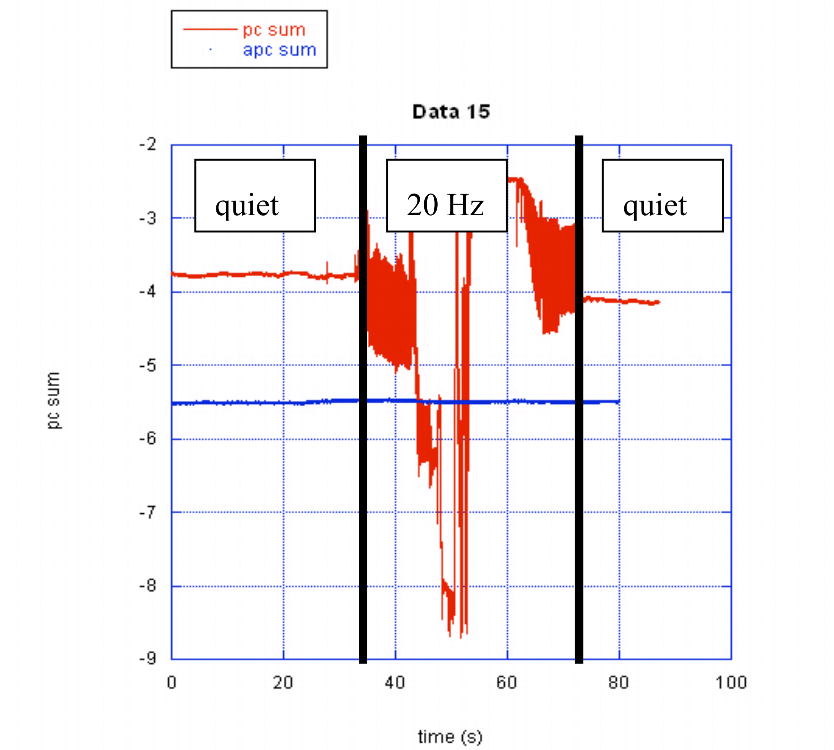
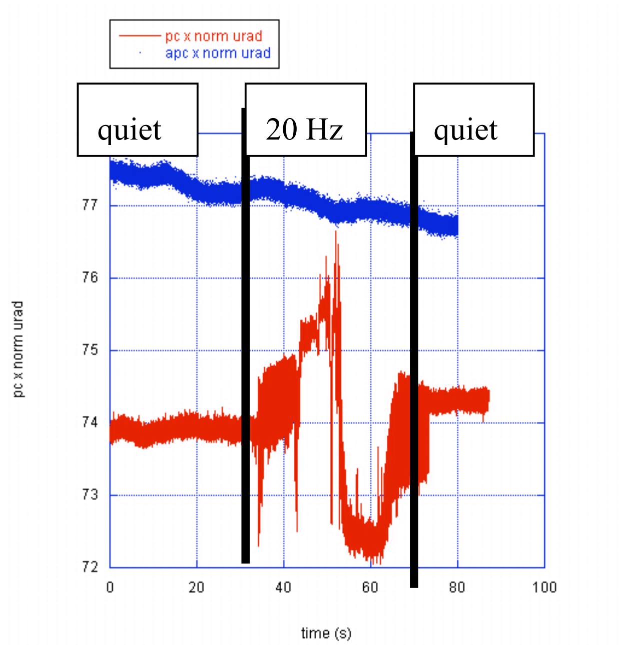
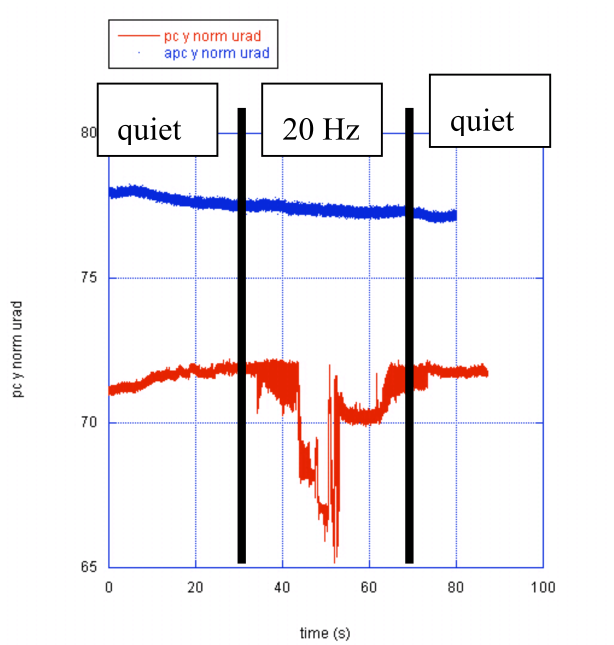


FIGURE 4 Plot of Vsum[Volts] between PC and APC vs time[s], 1.5V away from the gap. The APC fiber can maintain power stability much better than the PC fiber during the shake (30s < t < 70s.)





X norm in urad, between PC and APC **Y norm in urad, between PC and APC**

FIGURE 5 Left, comparison X(urad) vs time between PC and APC. Right, comparison Y(urad) vs time between PC and APC

APC fiber has higher stability in the total power of the laser. Both fibers appear to have the same pointing stability in x and y directions near the cross hair. However, APC is insensitive to fiber shaking.

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4 Test on APC pigtail laser

Having identified the problems as likely coming from reflections back to the laser from the perpendicular cut fiber, and realizing that the laser pigtail fiber has the same problem, we procured a new custom laser with APC pigtail fiber from Thorlabs. We repeat the stability test on the new pigtail laser. All components in use from now on will be APC and the back reflecting effect will be minimized.

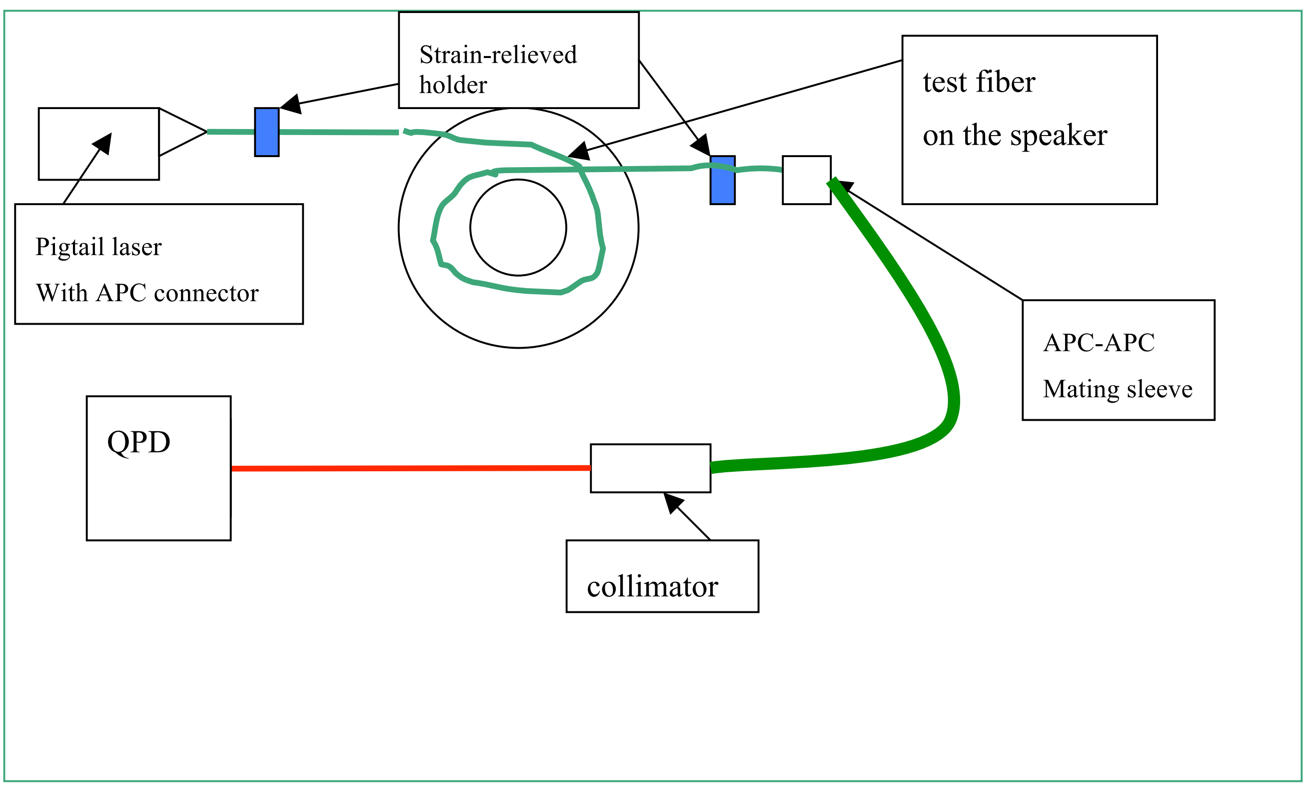

FIGURE 6 Setup for testing the vibration on the pigtail fiber of the laser.

The loud speaker shakes the fiber at 0(quiet), 20, 40, 100, 10, and 0 Hz. Each frequency lasts about 20 seconds. The experiments are done when the beam is 1) centered at the QPD 2) off centered by 150mV on both directions.

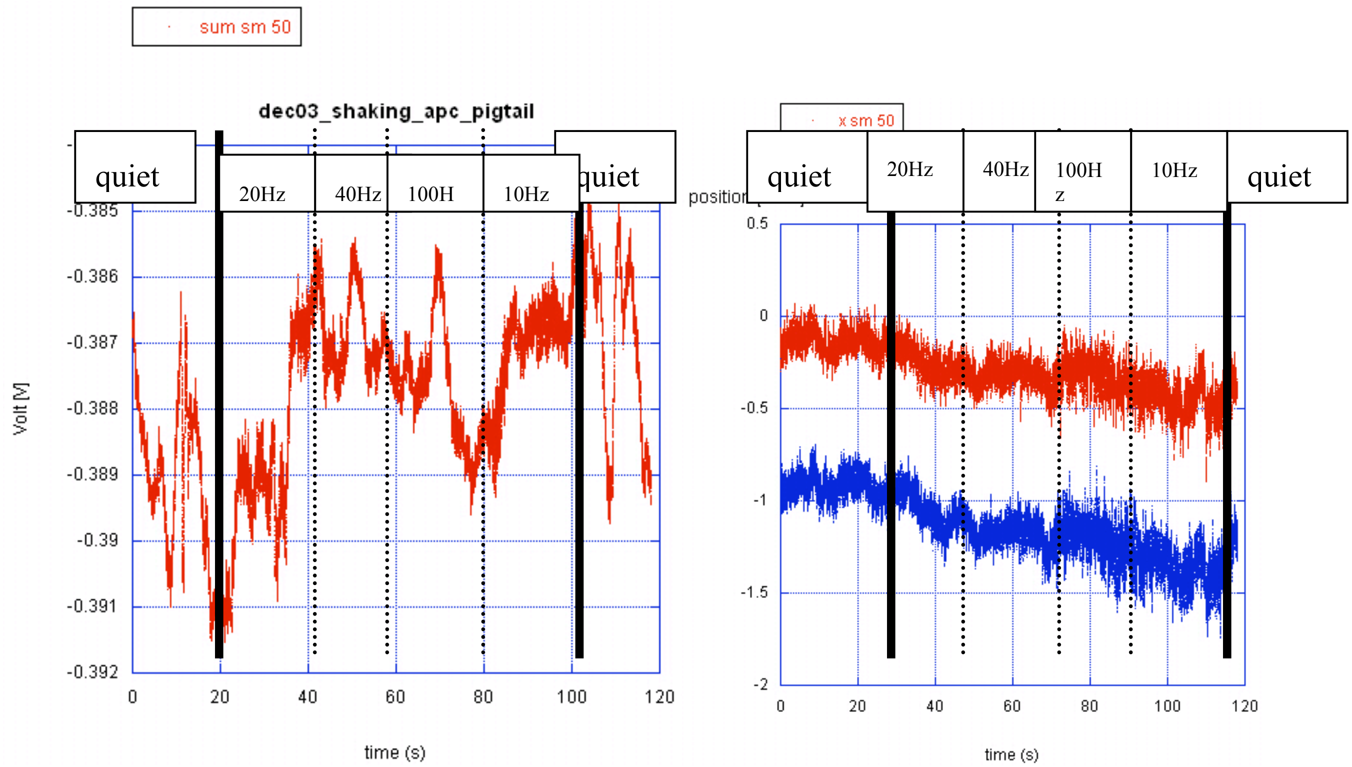

FIGURE 7 When the beam is centered on the QPD. Left, sum channel, no apparent difference between the shaken period (20 to 100 s) and the non shaken time (before 20 s and after 100 s.) Right, x and y in micro radian. More noise can be seen above 70 s but not clearly associated with the shaking.

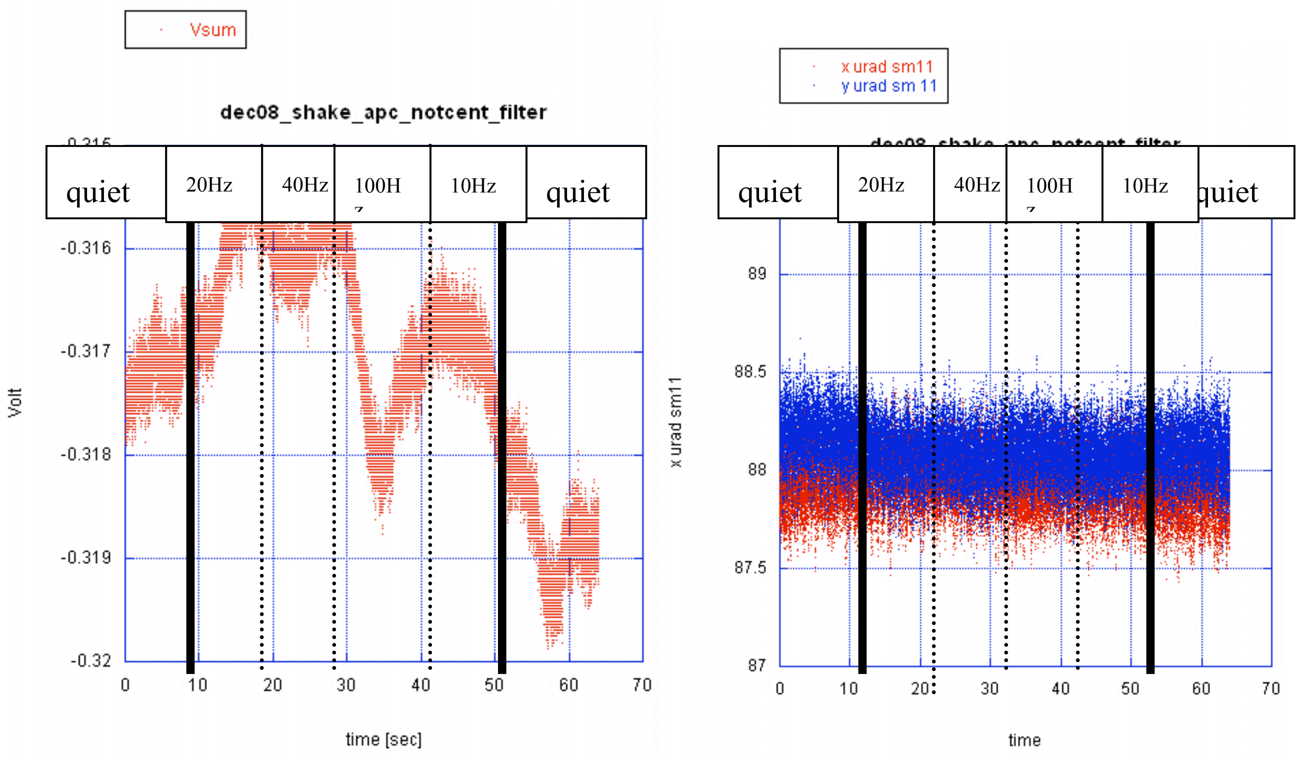

FIGURE 8 When the beam is off center. Left, sum channel, right, x and y in micro radian. This time each movement lasts only 10 seconds, hence the total time is about 60 seconds. No effect is associated with the shaking.

To make sure that the signal is really immune to the vibration, the power spectrum of the signal is shown below and compared between quiet and shaken fiber.

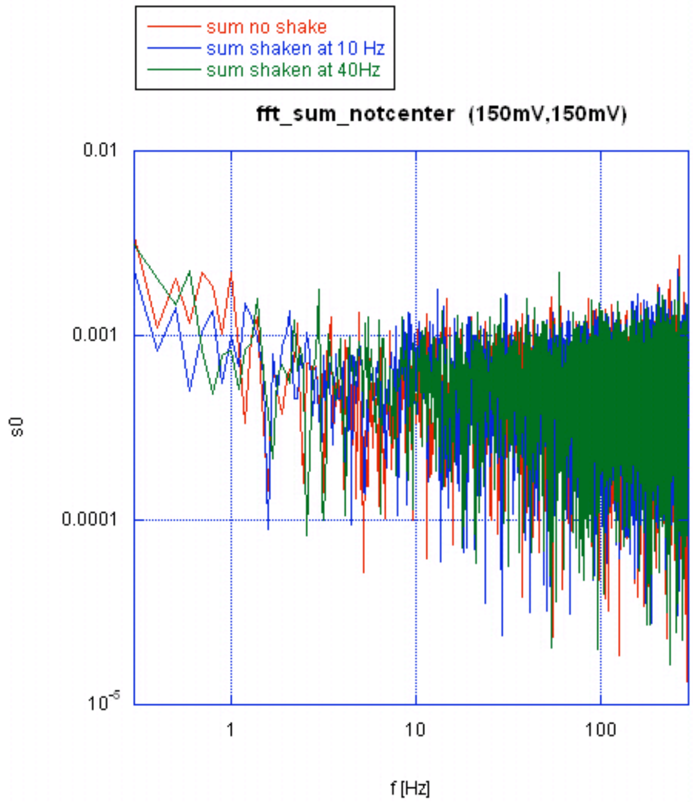

FIGURE 9 Plot between Volt/Sqrt[Hz] and frequency for sum channel. The peaks at 10 Hz and 40 Hz are only about twice larger than the ground noise.

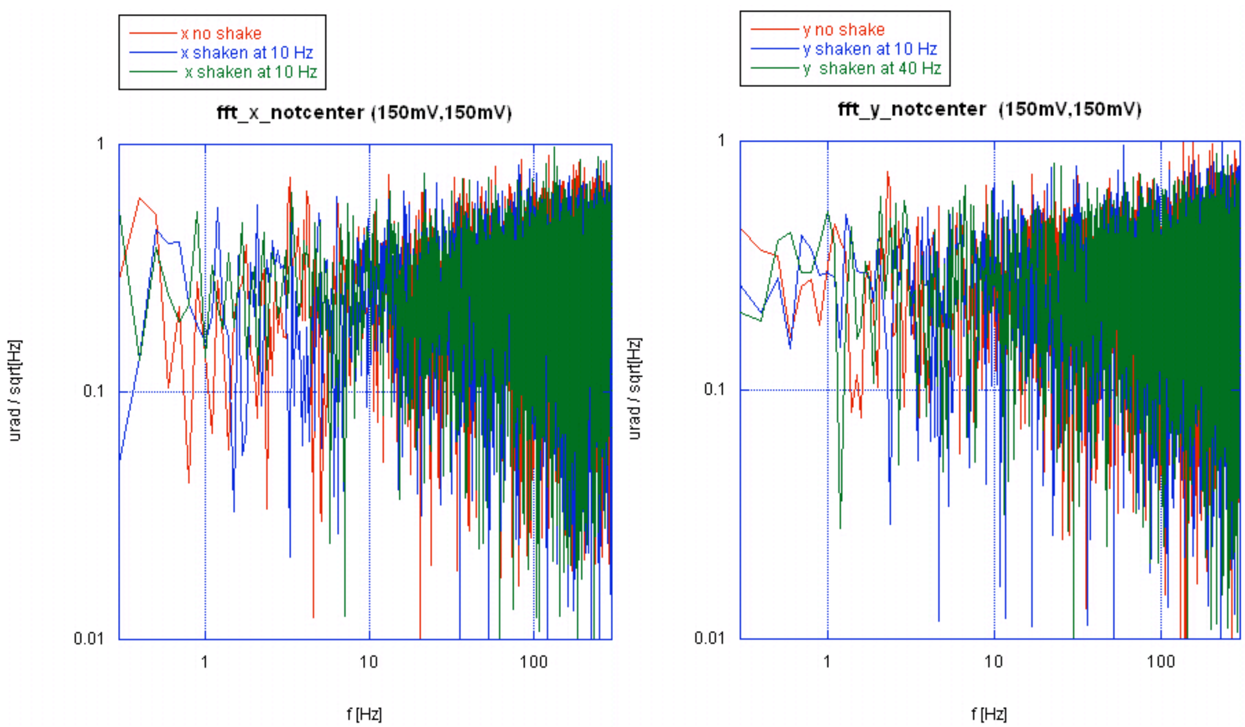

Figure 10 Plot between micro radian/Sqrt[Hz] and frequency for normalized x and y. No significant peaks occur at 10 and 40 Hz.

5 Summary

The results show that changing PC to APC fibers can reduce the fiber vibration induced shift in an apparent beam position. The shift might be caused by the back reflecting light at the connector of the fiber which feeds back to the laser and sets off the instability. Hence, better stability can be obtained by using APC fibers.