A NOVEL TWIN DRIVE TUNER MECHANISM FOR 1.3 GHz ILC CAVITY

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Abstract

We propose a new tuner mechanism for the 1.3 GHz ILC cavity named a twin-drive tuner. A bellow is provided in the central portion of the helium tank in the longitudinal direction, and flanges are provided on both sides of the bellows. A linear motion actuator is mounted to the flange on one side, and the frequency is changed by pushing and pulling the flange on the opposite side. Significantly, two linear motion actuators are placed in circumference and working simultaneously. A prototype tuner was developed, and the frequency tuning was evaluated. The displacement between the flanges and the frequency are proportional, both have good linearity, and the slope is 296 kHz/mm.

INTORODUCTION

A tuner is a device that mechanically deforms a cavity to change the natural frequency. Since the superconducting cavity is cooled by liquid helium, it shrinks from room temperature, and the natural frequency drops. Therefore, expanding the cavity to match the desired operating frequency is necessary. The tuner mechanism for the 1.3 GHz ILC cavity is described in the ILC Technical Design Report (TDR) [1]. Three mechanisms (blade, lever, slide-jack) have been proposed, all expanding and compressing the cavity in the longitudinal direction. Of these, the blade tuner was adopted. E-XFEL in Germany and LCLS-II in the US are large accelerators that use 1.3 GHz TESLA cavities. These accelerators adopted the lever tuner [2, 3]. The E-XFEL and LCLS-II have different helium tank and tuner designs. A lever tuner is located on the pickup side of the cavity and is mounted between the helium tank and a conical flange welded onto the beam tube. The cavity expands and compresses by operating the tuner. The lever tuner was reported as having a low manufacturing cost. Each has a production result of several hundred units.

The author proposes a novel tuner for a 1.3 GHz ILC cavity, which differs from conventional tuners. Here, we explain the mechanism of the proposed twin-drive tuner and show the developed prototype and performance evaluation test results.

PROPOSAL OF A NEW TUNER MECHANISM

An overview of the new tuner mechanism is shown in Fig. 1 [4]. A bellow is equipped so the helium tank can expand and compress in the longitudinal direction. Flanges are provided on both sides of the bellow, and an actuator varies the distance between these flanges. Like the blade and slide-jack tuners, it is placed on the outer circumference of the helium tank. Two actuators are mounted at opposite positions on the circumference. Each actuator comprises a linear motion actuator for coarse tuning and a piezo actuator for fine tuning. Figure 1 assumes that the cavity is elongated. The specifications required for tuner design are shown in the TDR, some of which are shown in Table 1. The tuning frequency range is 600 kHz. The 9-cell cavity and the helium tank are assembled by welding, and the longitudinal stiffness (spring constant) is 3 kN/mm. Therefore, the required stroke of the tuner is about 2 mm, and the maximum loading force is 6 kN. A twin-drive tuner requires a loading force of 3 kN per unit because two actuators share it. The use of an actuator with a large loading force simplifies the mechanism. The lever tuner uses a double lever mechanism to increase the force by 1:20 [3]. In the proposed scheme, there is no mechanism for power boosting. A piezo actuator for fine movement is arranged in series with the linear actuator. Repeated expansion and compression operation is performed at a high frequency to cancel the cavity's deformation due to the Lorentz force during the pulse operation of the accelerator. Maximum stroke is 3 µm.

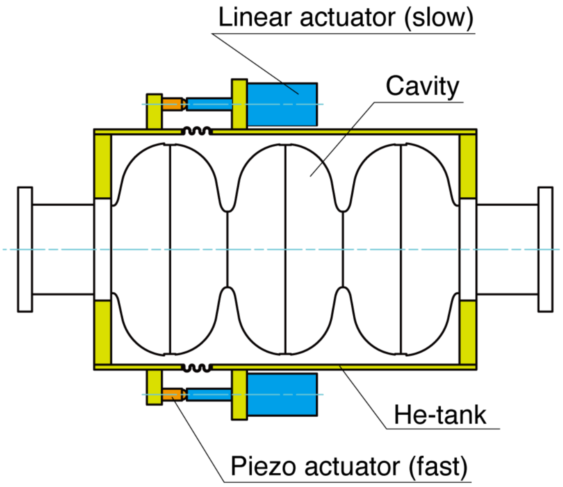

Figure 1: Schematic view of new tuner mechanism.

Table 1: Specifications of ILC Tuner Parameters and Experiment Results

Parameters	Specifications	Experiment results
Cavity elongation tuning $\Delta f/\Delta L$ [kHz/mm]	315	296
Cavity spring constant [kN/mm]	3	2.7
Slow tuner frequency range [kHz]	600	400
Slow tuner dimensional range [mm]	2 (~600/315)	1.3
Required loading force [kN]	6 (3x2)	3.6

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PROTOTYPING AND EVALUATION OF TUNERS

A prototype was developed to confirm that the proposed tuner mechanism works well. Here, the piezo actuator is omitted, and only the coarse motion is evaluated. First, the linear actuator is described. A compact actuator with a diameter of 60 mm or less is required to be placed around the helium tank. The Phytron product adopted for LCLS-II has a diameter of 52 mm and a maximum loading force of 1.3 kN [5], which does not meet this specification. Since there is nothing available on the market, we developed it ourselves. As shown in Fig. 2, the nut of a commercially available sliding screw (M12x2) was directly connected to the output of a commercially available stepping motor (42 mm square, with a reduction gear with a reduction ratio of 100). The screw and nut materials are stainless and plastic (poly phenylene sulfide). The screw moves forward and back to generate a loading force. When the tip of the screw is pressed against the load cell, and the force is measured, a maximum of 4 kN is obtained. In addition, it is the measurement in the air at room temperature. Evaluation in vacuum and low temperature has yet to be carried out. The results of the tuner evaluation test, which will be described later, are also in the air at room temperature.

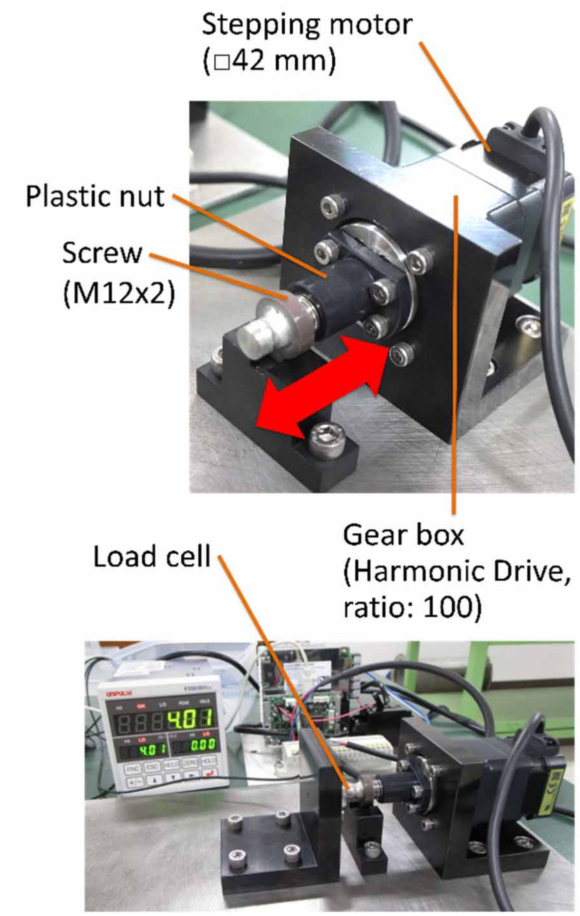

Figure 2: Linea actuator for slow tuning developed by ourselves.

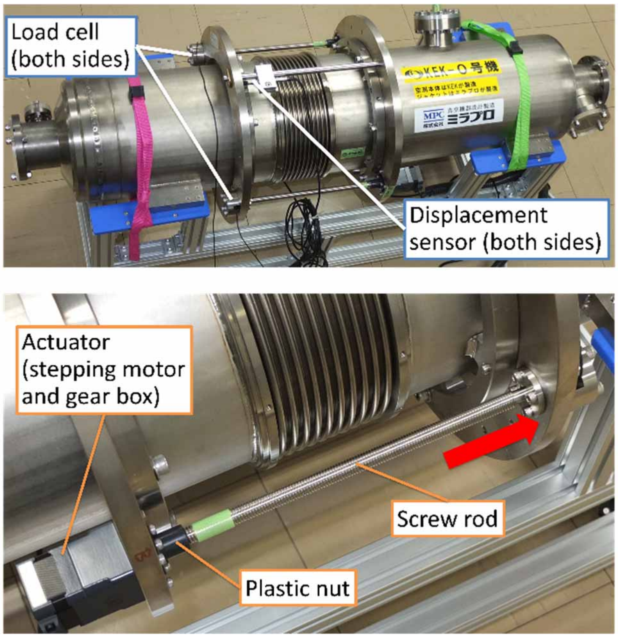

Figure 3: Appearance of the twin-drive tuner prototype.

Figure 3 shows the appearance of the twin-drive tuner prototype. A flange was added to the helium tank to which the blade tuner was attached, and two linear actuators were attached. Piezo actuators are omitted. A load cell was installed between the tip of the screw rod and the flange, and a displacement sensor was installed between the flanges to measure the load and the displacement. Furthermore, a network analyzer was connected to measure the natural frequency. The following tests were conducted using this prototype.

- Simultaneously input 2500 pulses (equivalent to 0.1 mm movement) as an instruction value to two stepping motors, which causes the helium tank to expand.
- Record the force, displacement, and the frequency.
- Repeat the above steps up to the equivalent of 2 mm.
- Simultaneously input -2500 pulses (equivalent to -0.1 mm movement) as an instruction value to two stepping motors, which causes the helium tank to shrink.
- Record the force, displacement, and the frequency.
- Repeat the above steps to the equivalent of 0 mm.

Figure 4 shows the relationship between the instruction value, the load, and the displacement. The two load cells showed almost the same value. The displacement is about 65% of the command value, which is small. Figure 5 shows the relationship between the displacement, the frequency, and the loading force. It is good linearity between displacement and frequency and small hysteresis. It was possible to tune the frequency in the range of 400 kHz. The cavity elongation tuning $\Delta f/\Delta L = 296$ kHz/mm was obtained. The combined rigidity of the helium tank and cavity is 2.7 kN/mm. These experimental results are shown together in Table 1. The tuning range is slightly smaller than the ILC specification. It was confirmed that the proposed twin-drive tuner mechanism works well as a tuner.

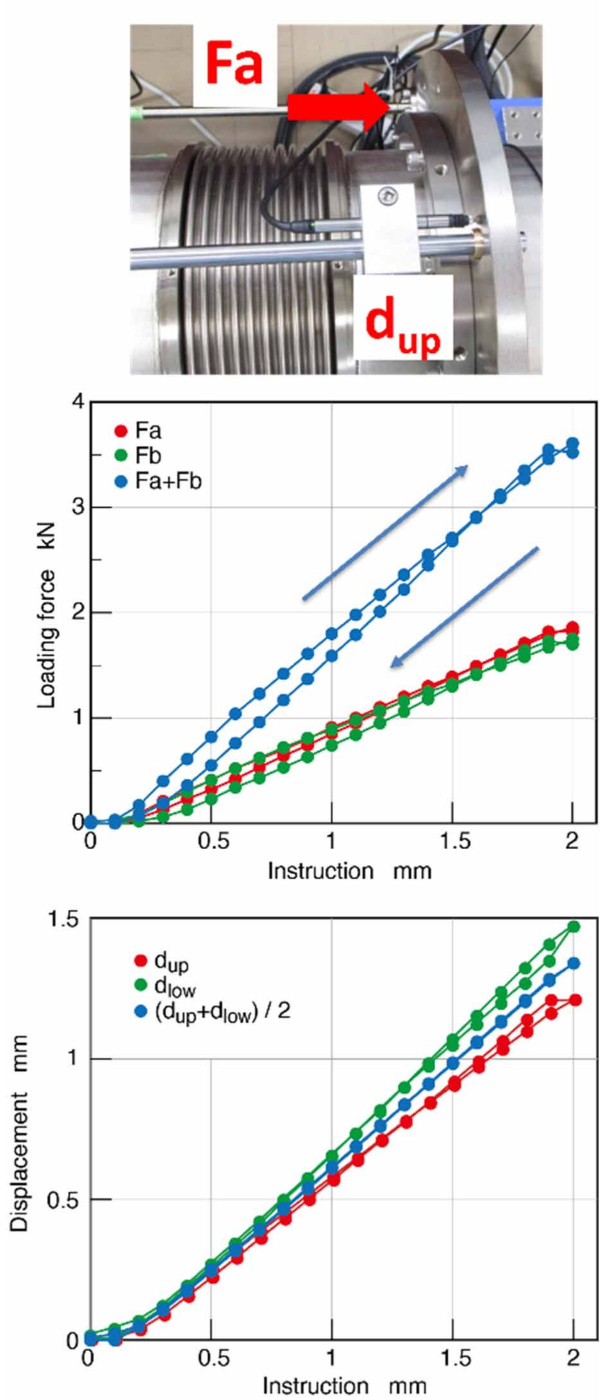

Figure 4: Relationship between the instruction value, the load, and the displacement.

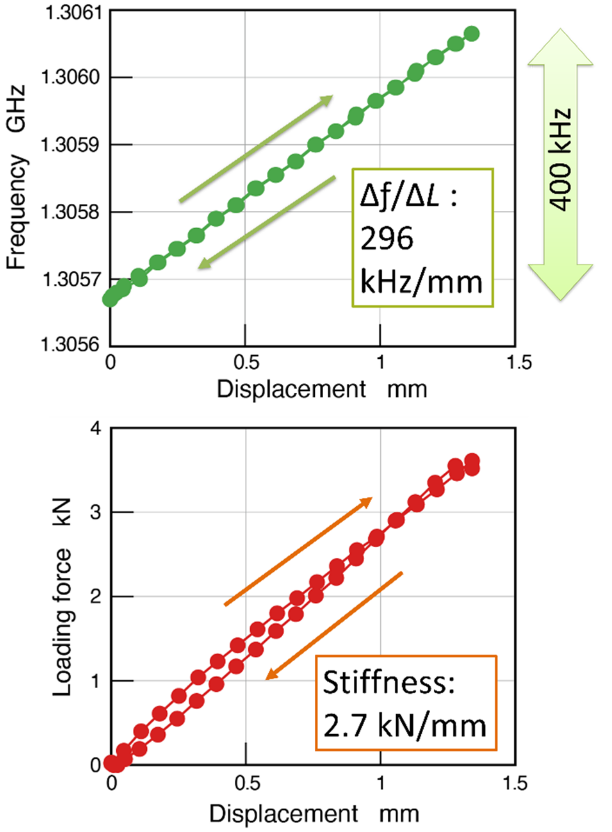

Figure 5: Relationship between the displacement, the frequency, and the loading force.

ACKNOWLEDGMENT

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