Project name

Linac and Final Doublet movers: 50 - 10 nm step, low vibration, radiation hard

Classification (accelerator/detector:subsystem)

Accelerator

Institutions and personnel

Colorado State University, Department of Physics:
David W. Warner (engineer), Robert J. Wilson (professor), Abner Soffer (research scientist)

Stanford Linear Accelerator Center:
Gordon Bowden (staff engineer)

Contact person

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Project Overview

Every magnet and structure girder in the linac will sit on movers to allow it to be positioned accurately. The movers will be required to position the beam components in five degrees of freedom: three linear positions and two angles. Two varieties of movers are required, distinguished primarily by their minimum step size and the number required (see Table 1). While the requirements for the two movers are significantly different, there are sufficient similarities to warrant attempting to develop a design with many common elements to reduce costs and ease production.

	Linac Component	Final Doublet
Resolution	1.0 micron	0.1 micron
Range	2.0 mm total	1.0 mm total
Stability	1 micron/day	0.5 micron/day
Max Velocity	2mm/min	2mm/min
Load Capacity	250 kg	1 ton
Pwr(full speed)	20 watts	100 watts
Pwr(static)	<2 watts	<2 watts
Cost(/10^4units)	$100 each	not an issue
Radiation Hard	yes	yes

Table 1: Requirements for Linac component and Final Doublet Movers (courtesy of Gordon Bowden)

Linac component movers will typically be adjusted every few minutes to hours. A step size of 50 nm is needed along with a total range of 1 mm. It is important to have a high quality, reliable, inexpensive system for this. Gordon Bowden has developed and produced movers that meet the requirements listed in table 1 except for step size which have been used in the FFTB. These movers are purely mechanical, providing motion by rotation of a shaft with eccentric cams in contact with a bearing plate. Mechanical movers such as these have several desirable features, including low cost, reliability, and the ability to retain a set point without active compensation. A prototype version of the stepper motor driver allowing for micro stepping has been developed which may provide the required step size for the mover, but it still requires calibration to determine if it is providing 50 micron steps. If the mechanical prototype can be demonstrated to provide the required step size and repeatability, then this phase of the project would consist of fine-tuning the existing design. The stepper motors, for example, complicate use in a magnetic field; so replacing them with another driver would be desirable. Cost reduction and design-for-manufacturability issues would also be important, since the large number of movers requires a low cost. If the mechanical motion alone is not accurate enough to accomplish the 50 nm step size required, then a combination of the mechanical mover and a piezoelectric stack will be investigated. This approach is envisioned for the final doublet movers.

The final doublet movers are a more complicated device, requiring 10 nm step size, excellent stability against vibration, and possible operation in a cryogenic environment. Similar step sizes and vibration isolation have been accomplished for STM applications, using a combination of a mechanical mover (for coarse adjustment) and a piezoelectric stack. Piezoelectric stacks are notoriously unstable, and require constant feedback and adjustment to maintain the set position. We would investigate using a mechanical mover similar to the linac movers, with a piezoelectric stack for precision movement and an interferometer providing continuous feedback to keep the system at the set-point. Note that we would not envision using the interferometer for absolute position measurement—that would be accomplished by beam monitoring. The interferometry would be used solely to maintain the position of the mover.

Description of first year project activities

Phase one of this project consists of studying the linac component by Bowden *et al.* for use in the FFTB. Using a Michelson-Morley interferometer, we will conduct precise measurements to determine if this apparatus is capable of producing the required accuracy if driven by a micro-step stepping motor. Additionally, we will investigate driver systems (motors) capable of operating in a 4-Tesla field and at extremely low temperatures.

Phase two of the project is to reduce the step size attainable by the mover by incorporating piezoelectric movers and active feedback. After gaining an understanding of the limitations of the mechanical mover, we will attach a piezoelectric stack to the mover, along with an interferometry-based feedback system, and determine the step size, vibration isolation, and stability achievable with such a system.

The deliverables at the end of the project would be:

- -Measurements of the step size achievable using the micro-step driven FFTB mover
- -Measurements of the step size and stability achievable using a combination of a modified FFTB mover and a piezo stack with interferometry-based feedback
- -Initial work towards developing a manufacturable mover for both beam-line components and the final doublets

This project is an excellent fit with the capabilities of the technical design facility at Colorado State University. David Warner will be the principal technical participant on this project. Wilson and Soffer will provide general and logistical support as needed.

Future work will involve incorporating the information gained during this proposal period into prototype devices, and prepare a design for mass production.

We envision this proposal as the beginning of a larger CSU involvement in mechanical aspects of the linac development effort. If we can identify other areas where a group of our size and with our facilities can contribute to the effort, in future years we would expect to be able to expand our involvement to perhaps 50% of a FTE engineer (Warner).

Preliminary Budget Estimate

Institution	Item	Cost (k$)
CSU	Piezoelectric stack & Interferometry equipment	10.0
CSU	Personnel costs for Technical Design Facility	23.0
CSU	Indirect costs	14.9
CSU	Total	47.9