Beam Profile Measurements Utilizing an Amplitude Modulated Pulsed Fiber Laser at PIP2IT *

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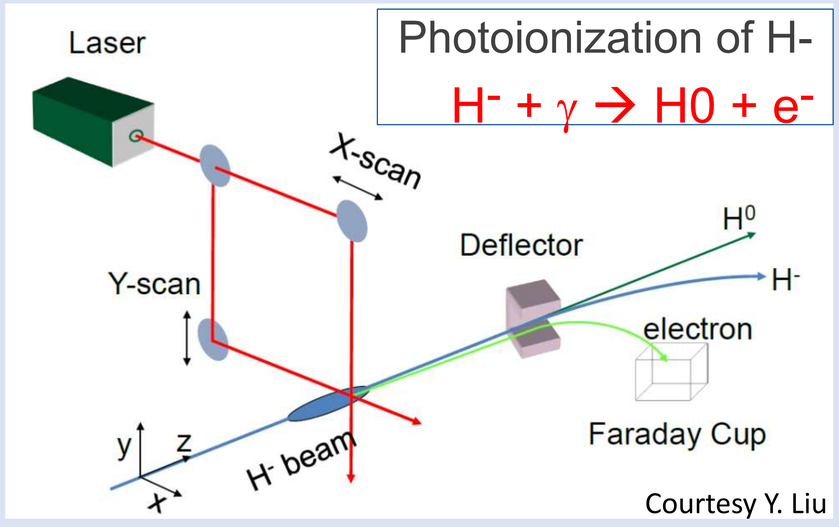
Abstract

Fermilab is undertaking the development of a new 800 MeV superconducting RF linac to replace its present normal conducting 400 MeV linac. The PIP-II linac consists of a warm front-end generating 2 mA of 2.1 MeV H- followed immediately by a series of superconducting RF cryomodules to 800 MeV. To limit the potential damage to the superconducting RF cavities, PIP-II will utilize laser-based monitors to obtain beam profiles via photoionization. This paper will present the results of transverse and longitudinal beam profile measurements using a prototype profile monitor that was tested with 2.1 MeV H- beam at the PIP-II Injector Test (PIP2IT) accelerator. This prototype profile monitor utilizes a high repetition rate fiber laser and fiber optic transport into the PIP2IT enclosure. In addition, results will be shown of narrow-band electron detection from amplitude modulated laser pulses.



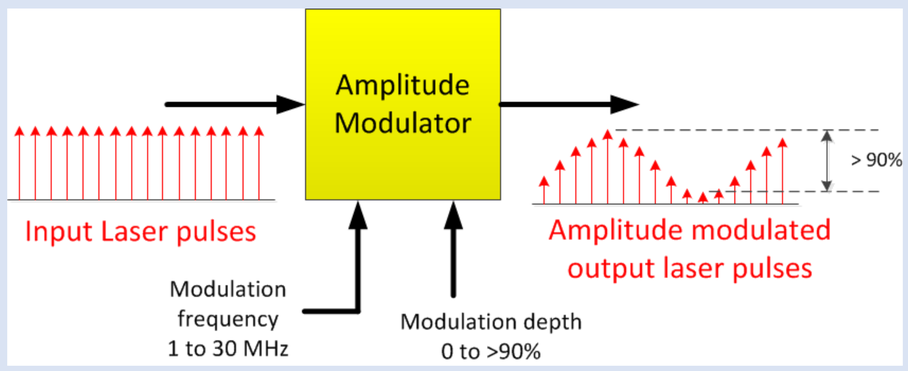
Photoionization of H-

$H^- + \gamma \rightarrow H0 + e^-$

Some issues for PIP-II
- 3.5 E–17 cm^2 at 1.17 eV (λ = 1064 nm)
- Small cross section → small signal
- PIP-II low beam current → small signal
- Laser power limited by damage limit on optical vacuum viewports
- pA up to ~1 nA expected signal

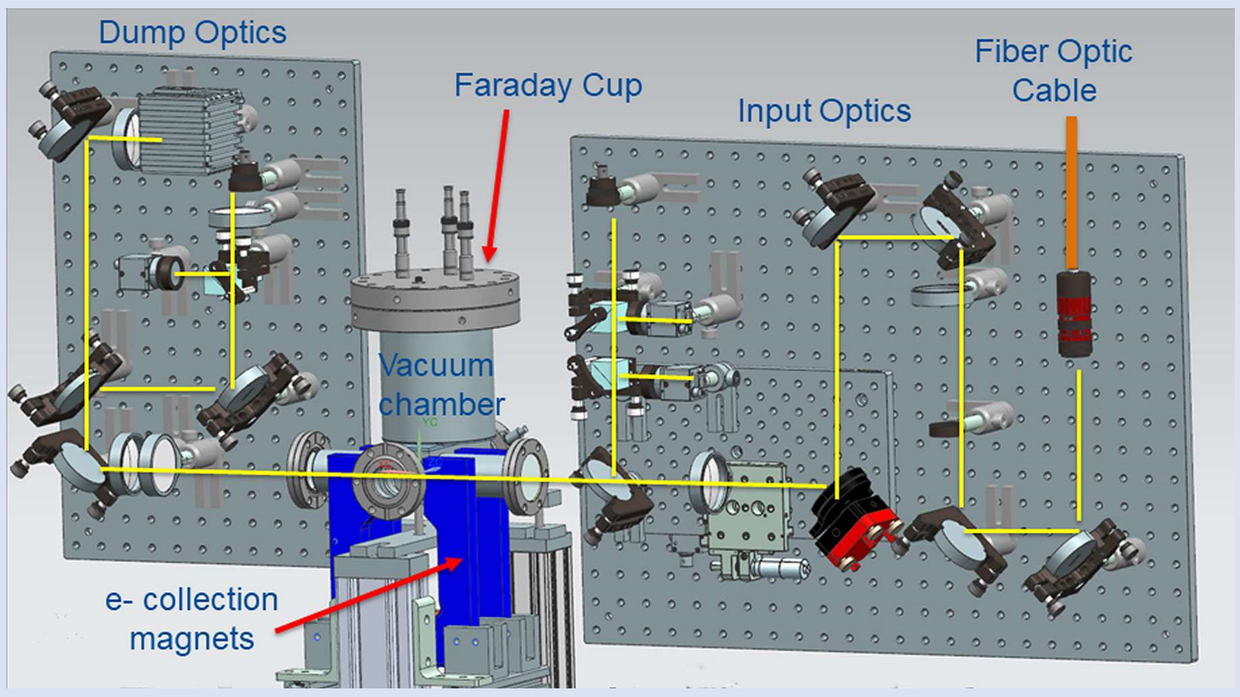
H- Beam Parameters
- 162.5 MHz beam, 2 mA average
- 2.1 MeV H-

Fiber Laser Parameters
- Ytterbium fiber seed laser + amp
- Up to 1 W
- 162.5 MHz pulse of 12 ps FWHM

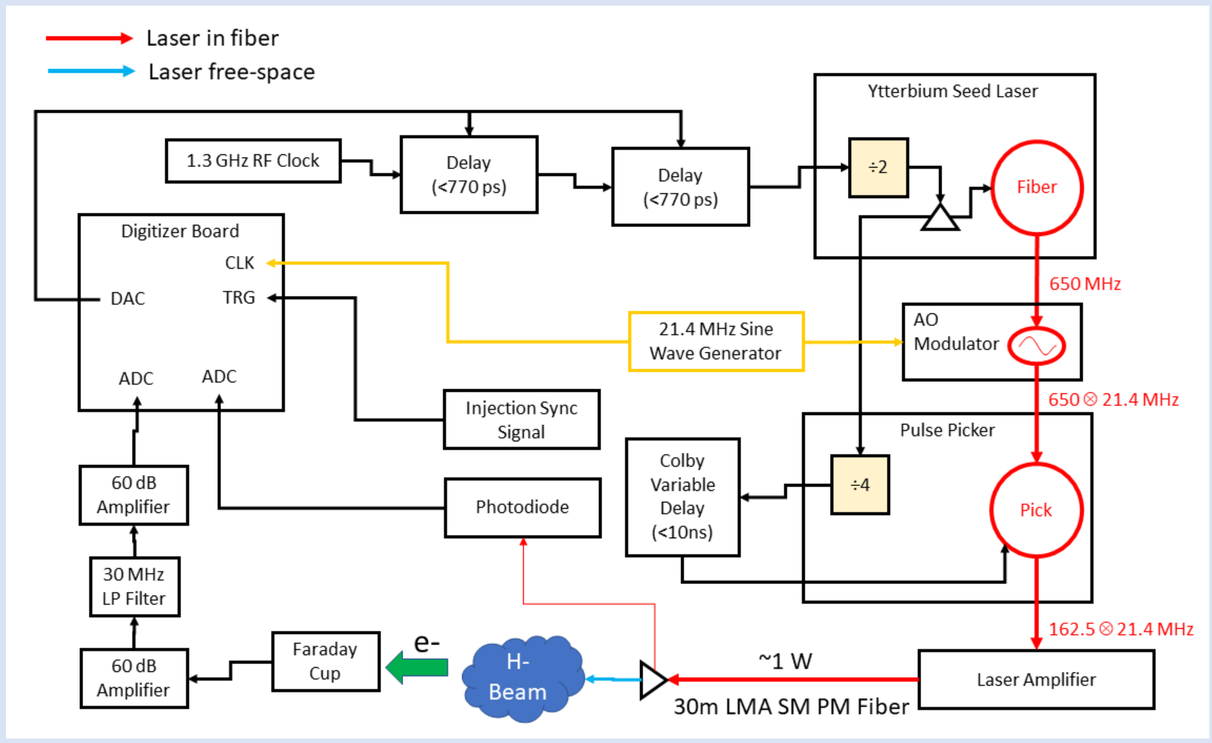


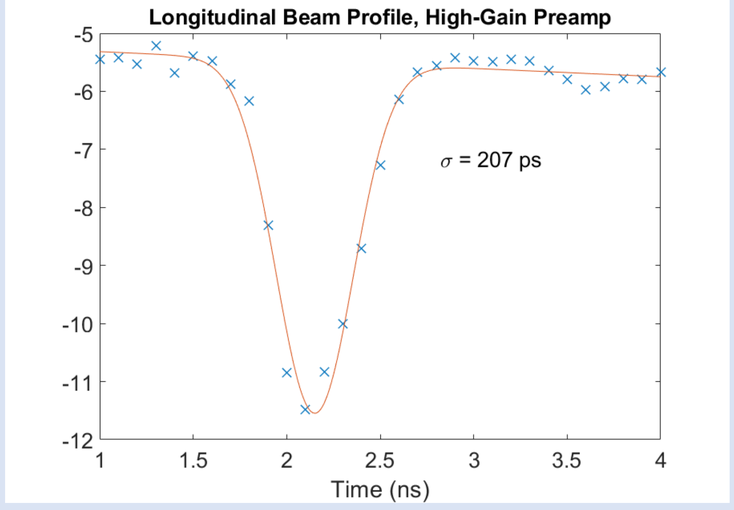
- Laser rep-rate is locked to accelerator RF → one laser pulse per H- beam pulse
- Amplitude modulate laser pulses at 21.4 MHz
- Transport modulated laser pulses to beamline via 30m of SM LMA PM fiber
- Measure profiles by collecting electrons in Faraday cup
- Digitizer board locked to modulation frequency
- Narrow-band lock-in amp detects modulated signal
- Digitizer locked to modulation frequency allows for lock-in on pulsed data
  - Allows for greater sensitivity and noise reduction
- Longitudinal profiles by shifting phase of seed laser

Optical Layout



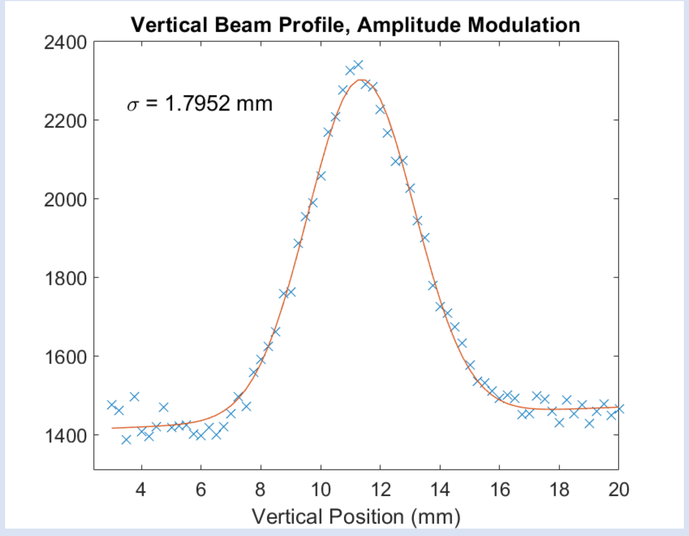
Laser Profiler System Diagram





Longitudinal beam profile with high-gain preamp
- No *modulation*
- *Preamp noise requires averaging*
- Background electrons limit dynamic range of measurement

Vertical beam profile with laser amplitude modulation detection
- Potentially very sensitive technique
- Sensitivity is proportional to time
- Limited by cross-talk effects



Summary

A prototype H- transverse and longitudinal beam profiler based on an amplitude modulated fiber laser source was constructed and tested at the PIP2IT accelerator. This prototype unit successful demonstrated a lock-in amp technique to make beam profiles from amplitude modulated laser pulses. In addition, locking the DAQ system to the same modulation frequency allowed the lock-in amp technique to be used for pulsed signals.

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