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**A Coherent FMCW LIDAR Mapping System for
Automated Tissue Debridment**

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A COHERENT FMCW LIDAR MAPPING SYSTEM FOR AUTOMATED TISSUE DEBRIDMENT

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Abstract

The Oak Ridge National Laboratory (ORNL) is developing a prototype 850-nm FMCW lidar system for mapping tissue damage in burn cases for the U.S. Army Medical Research and Material Command. The laser system will provide a 3D-image map of the burn and surrounding area and provide tissue damage assessment.

A COHERENT FMCW LIDAR MAPPING SYSTEM FOR AUTOMATED TISSUE DEBRIDMENT

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Introduction

The Oak Ridge National Laboratory (ORNL) is developing a prototype 850-nm FMCW lidar system for mapping tissue damage in burn cases for the U.S. Army Medical Research and Material Command. The first phase of this project involved the development a prototype FMCW laser radar system for mapping tissue damage in burn cases for the U.S. Army Medical Research and Material Command. In its final form, the laser system will provide a 3-D image map of the burn and surrounding area and provide tissue damage assessment. The local coordinates of the damaged tissue will be reconciled with real-world coordinates for ultimately positioning and controlling a pulsed laser for automated removal of the dead or necrotic tissue.

Evaluation of Laser Interaction with Tissue

The first task was to chose the optimum laser wavelength for providing a return signal for ranging. The wavelength selection was derived from models available in the literature on IR laser interaction with tissue. The laser wavelength for this lidar system is in the near-infrared at 850 nm. This choice was based on two considerations: (1) Low relative absorption in skin and (2) high scattering from hemoglobin. 850 nm is near the minimum in skin absorption, while the absorption coefficient for whole blood is nearly 10 times higher. The "absorption" coefficient is primarily due to scattering, more so for blood than skin. Our initial model for the debridement measurement assumes a two layer target, the skin surface which reflects a portion of the incident light due to a Fresnel relectivity of ~3.5% (skin index of refraction ~1.31) and a layer containing blood in undamaged tissue below the burn damaged skin. The return laser signal should then contain primarily two components, one from the surface and one from the blood layer below the burn.

Development of FMCW Lidar Breadboard

Once the wavelength was chosen, a solid state laser at the appropriate wavelength was purchased and a prototype lidar system constructed. The lidar is a Michleson interferometer design with a chirped-frequency laser diode. The laser is a distributed-feedback diode, Model SDL- 5722-H1, which produces approximately 150-mW of power at a wavelength of 850-nm. The laser diode is isolated from stray-light feedback from the optics system with a ferrite isolator. In order to calibrate the lidar system, measurements were made of the thickness of a fused silica optical flat. The reference mirror was blocked for these measurements to simulate the return phase produced only by the thickness of the target. The blue curve in Figure 1 represents the captured return from a 0.6463-inch thick fused silica optical flat.

Measurement of thickness of 0.6463-inch fused silica optical flat

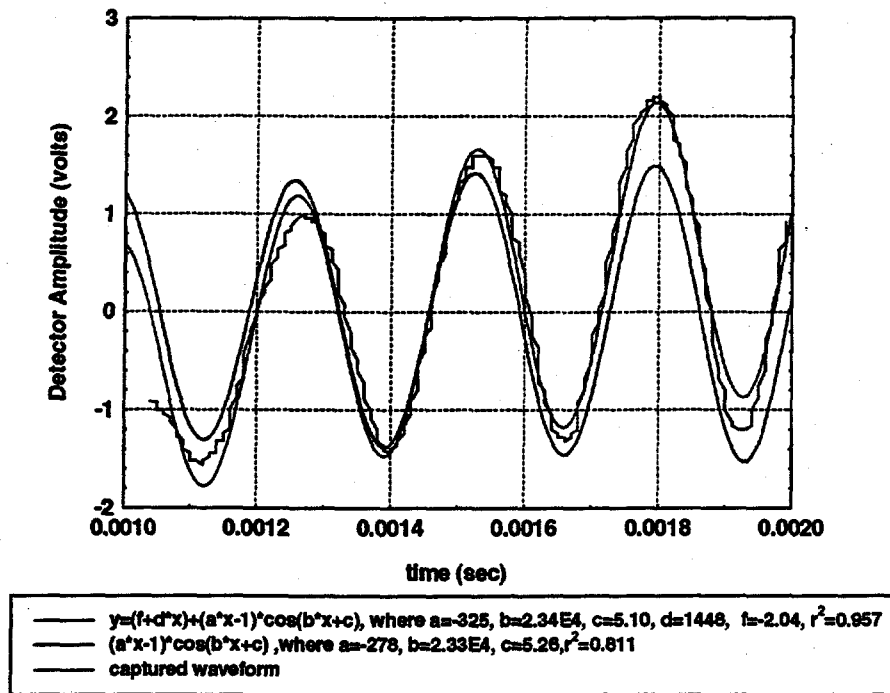


Figure 1 An optical flat is used to calibrate the lidar system.

The red curve is the best fit to a four parameter model that includes a ramp offset represented by the term “ $d*x + f$ ”, a ramping amplitude on the cosine term represented by the term “ $1+a*x$ ”, and the “ b ” term in the argument of the cosine is given by $b = 2\pi f$, where f is the measured beat frequency. For this optical flat the index of refraction, n , is 1.453. After the radian beat frequency “ b ” is determined from fitting the model to the captured waveform, the thickness of the flat may be calculated from the equation

$$t = \frac{bc}{4n\alpha}$$

- where t = thickness
- c = speed of light
- n = index of refraction
- α = bandwidth /sec of the laser chirp.

The calculated value of the thickness $t = 0.1672$ -mm, compared to a mechanically measured value of 0.16715-mm. The error is ~1.8% or approximately 300 microns. There are two factors not yet accounted for in our model. These parameters are (1) the linearity of the laser chirp, which we know from our observations is slightly non-linear, and (2) the exact value of α , the laser chirp bandwidth. The non-linearity of the chirp can be measured in real time with an additional detector we plan to incorporate in our system and the bandwidth can be determined with better accuracy with straight forward improvements in our optical set-up. We expect a measurement accuracy of 30-50 microns in our final system.