Vertical Laser Beam Intensity Through Earth's Troposphere

1   Introduction

Not long after demonstration of the first laser (May 16, 1960, by Dr. Theodore Maiman, Hughes Research Laboratory, California, USA), engineers and scientists began using lasers as part of free-space optical communications systems. It soon became evident that one of the key issues confronting this type of system was the atmospheric effects on laser beam intensity. Not only were laser beams being transmitted between buildings (optical fiber links were not yet available), but also between the surface of the Earth and satellites in geosynchronous orbit.

This analog computer application simulates the intensity of a laser beam as it propagates through Earth's troposphere, which is about 12 kilometers thick.

2   Mathematical modeling

A mathematical model for vertical laser beam intensity may be described by the coupled system of differential equations shown below. Typically, α is assumed constant for horizontal laser beam transmission, but it is not the case for a beam that is fired vertically.

$$\alpha' + \mu\alpha = 0 \text{ with initial condition } \alpha(0) = \alpha_0 \text{ and}$$

$$I' + \alpha I = 0 \text{ with initial condition } I(0) = I_0,$$

where $\alpha' = d\alpha/dy$, $I' = dI/dy$, α = absorption coefficient, y = altitude, μ = constant, and I = laser beam intensity
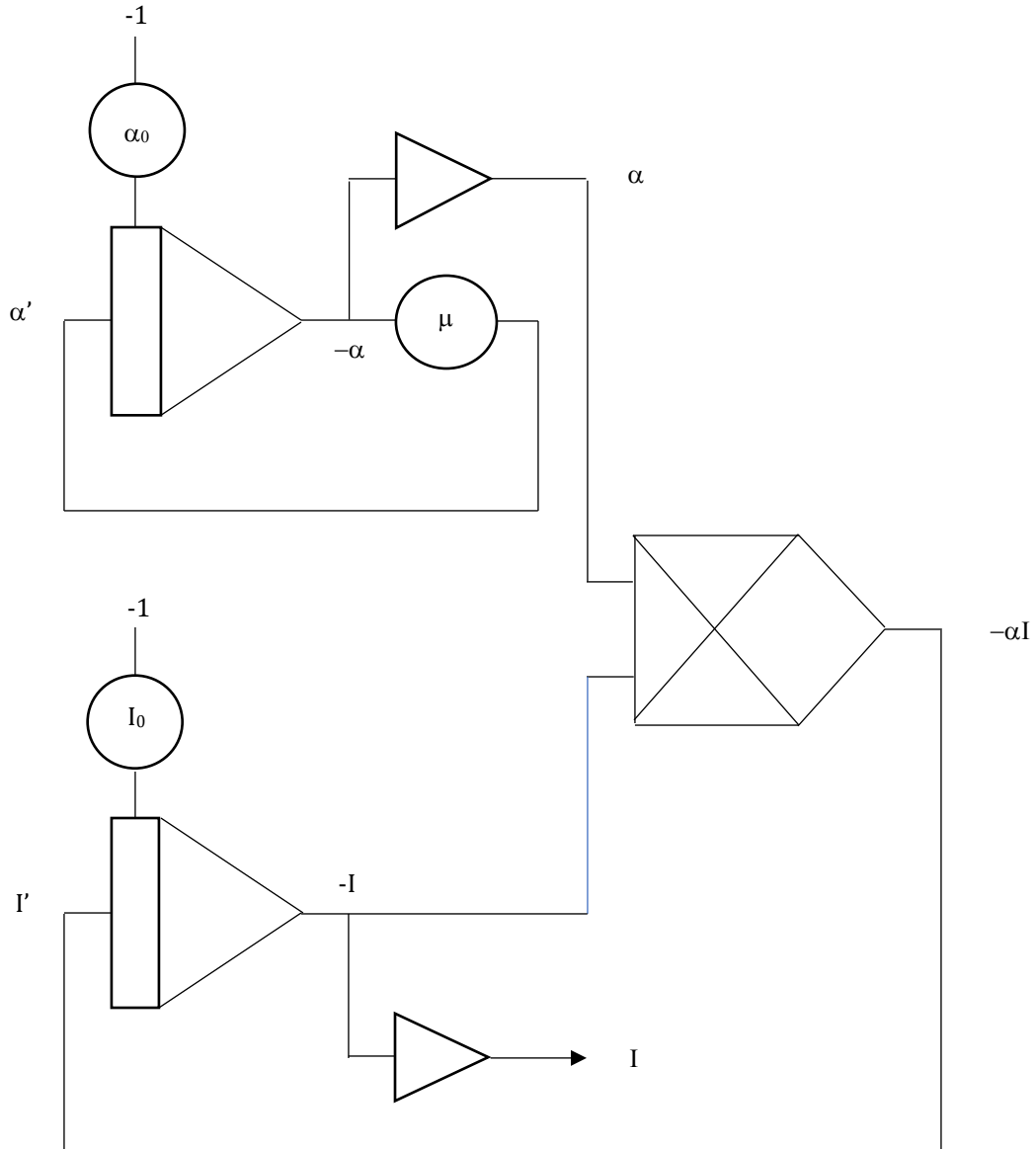
3 Computer setup

Figure 1: Computer setup for vertical laser beam intensity simulation

Parameter	Value
α_0	0.343
μ	0.242
I_0	0.322

Table 1: Parameter settings for vertical laser beam intensity

4   Result
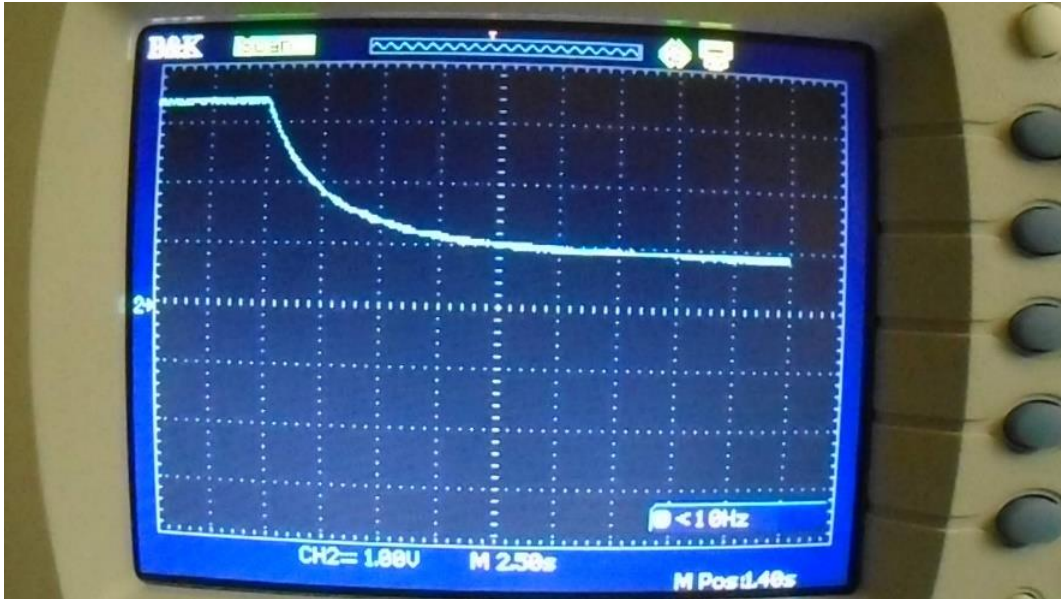

Figure 3: Laser beam intensity as a function of altitude*

*For this application note, the display was produced during a single run using a differential equation analog computer prototype electronic breadboard and discrete components with tolerances ranging from 1% to 10%.

Michael Cimorosi, Issue #1, 4-SEP-2020