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Computer Aided Simulation to Study the Effect of Atmospheric Turbulence on Ideal Gaussian Laser Beam Using Matlab and Lab-View

KEYWORDS Kolmogorov Phase screen, Atmospheric Turbulence, Gaussian Beam, TEM Modes, Lab-VIEW Mathscript RT Module, Beam Profiling.

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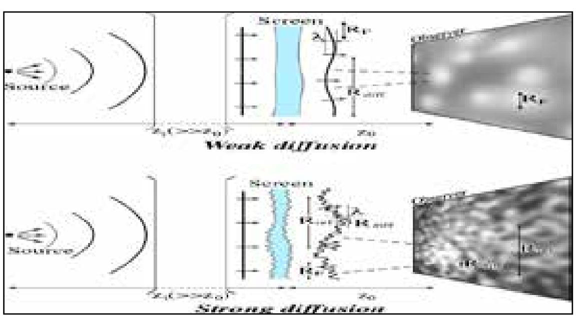
ABSTRACT *Gaussian Beam is a beam of electro-magnetic radiation whose traverse (Electric field & Intensity) disturbance are well approximated by Gaussian Function. In this paper, we simulated the effect of the atmospheric turbulence on the propagation of an ideal Gaussian Beam. To do this we created a Kolmogorov phase screen and integrated with an Ideal Gaussian Beam Using MATLAB and Lab-VIEW Integration. This will help in great deal to understand the propagation of laser beams in turbulent atmosphere with graphical appearance i.e., Beam Profiling. . Lab-VIEW (Laboratory Virtual Instrumentation Engineering Workbench) is a graphical programming language where flow of data determines the execution. A number of applications have been built using the Lab-VIEW like: Robotics, Instrumentation and Control, Signal processing etc. For the integration of MATLAB Program in Lab-VIEW We used Lab-VIEW Mathscript RT Module.*

Introduction:-

While propagating through the atmosphere, Laser spreads laterally due to diffraction. Because of the unique properties of Laser Beams, such as high brightness, a laser beam is relatively sensitive with respect to the microstructure of the atmospheric Turbulence. It is often observed, however, that laser beams have a tendency to wander randomly about their propagation direction (rectilinear path) while propagating through the atmosphere, and appear to accumulate fluctuations in their light intensity, called **scintillation** (see Fig 1 and 2)



While atmospheric turbulence is a stochastic process, there is 'structure' in randomness. Kolmogorov considered the simplified problem of a non-viscous and isotropic atmosphere, i.e., that the outer scale is infinity and the inner scale is zero. These assumptions indicates well-defined distribution for the randomness in the refractive index of the atmosphere, that can be applied in the laboratory Experiment. One of the key findings of Kolmogorov has been that the turbulence strength can be described by a single parameter, the atmospheric structure constant, Cn^2 . Large Cn^2 indicates strong turbulence , and vice versa.

Matlab® stands for Matrix LABoratory and the software is built up around vectors and matrices. It is widely used in all areas of education, applied mathematics and research at universities, R&D Departments and in the industry. The software particularly useful for linear algebra but MATLAB is also a great tool for solving algebraic and differential equations and for numerical integration. MATLAB has excellent graphic tools and can produce nice 2D and 3D pictures. MATLAB is also useful for signal & image processing, and optimization, etc .

In MATLAB we coded for generating a Kolmogorov phase screen and generating an Ideal Gaussian Beam.

Lab-VIEW stands for Laboratory Virtual Instrumentation Engineering Workbench. It is a platform and development environment for a visual programming language from National Instruments. The graphical language is named as 'G'. It has a broad field of application in education and research to work in real time environment. It has two panels namely Front Panel (where the real time observations are taken) and the Block Diagram (where the graphical programming is done).

In Lab-VIEW we designed a Virtual Instrument to observe the Kolmogorov turbulence in ideal Gaussian Beam that generates a 3D surface view of ideal Gaussian Beam, Kolmogorov phase screen and the turbulence affected Beam.

We used **Lab-VIEW MATHSCRIPT RT** Module to integrate Matlab Programming with the Lab-VIEW graphical program.

Lab-VIEW MATHSCRIPT RT can deploy **.m** file scripts as a part of Lab-VIEW application and combining graphical & textual programming. This can be done using Mathscript Node.

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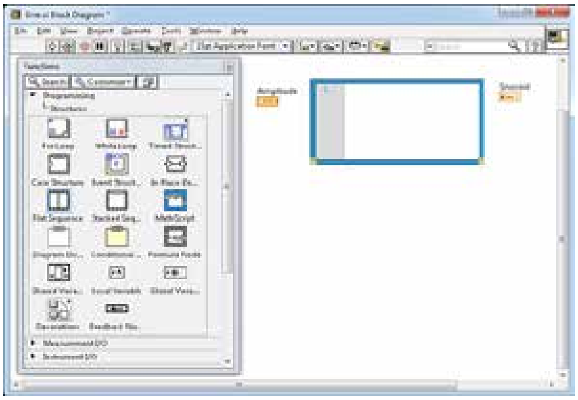


Using the Mathscript Node

Using Mathscript Node, One can enter **.m** file script text directly or import it from a text file.One can define named Input & Output on the Mathscript Node border to specify the data to transfer between the graphical Lab-View environment and the textual Mathscript Node.

Mathscript Node on the Block Diagram is represented by a blue Rectangle as shown in the following Figure.

Beam Profiling

In beam profiling we created plots of an ideal Gaussian beam as well as Kolmogorov turbulence affected beam i.e., 2D, 3D surface and contours. Using Matlab and Lab-VIEW integration.

Methodology

Creating Kolmogorov Phase Screen

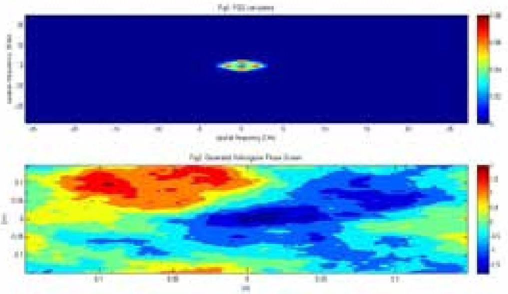
We generated Kolmogorov spectrum turbulence screens based on the power spectral density (PSD), which is well approximated by,

$$\Phi(f_s) \approx \frac{0.023}{r_0^{5/3}} f_s^{-11/3}$$

In the above equation, f_s is the spatial frequency and r_0 is the Fried coherence length, which is approximately the largest size of a telescope that is not significantly affected by atmospheric turbulence.

It is important to note that the spatial frequency spectrum does not vary based on Fried's coherence length.

The following figure (Fig1, 2) shows the PSD Calculated and the Kolmogorov phase screen generated using MATLAB®.



After generating phase screen, we integrated it with ideal Gaussian laser beam and observed the various effects.

For the integration we wrote the MATLAB codes in the Lab-VIEW Mathscript Node once again and applied the concept of G-programming as shown in Fig 3.,to generate various plots like Contour,3D surface plot etc., for the ideal Gaussian as well as the final result after beam getting turbulence.

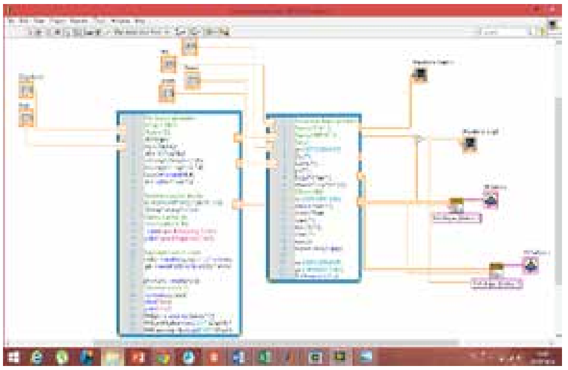


Fig3: Lab-View Program for Atmospheric Turbulence in ideal Gaussian Beam.

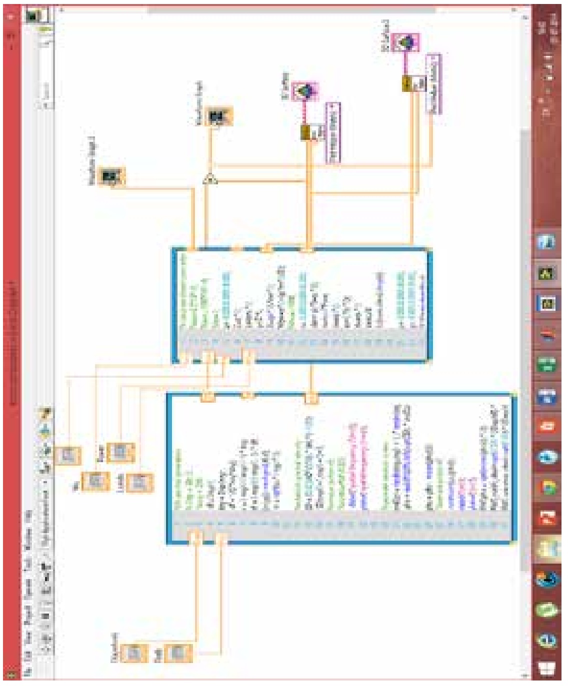
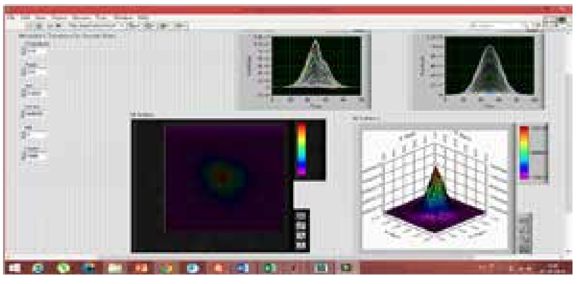


Fig4: MATLAB & Lab-VIEW INTEGRATION FOR ATMOSPHERIC TURBULENCE.

Result

After Completing the programming results obtained are Plotted as Shown in Fig 4.



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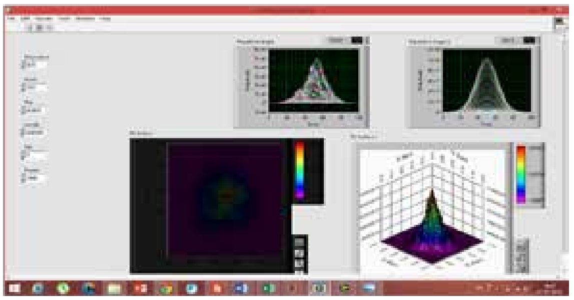

Fig4:Lab-View Program Output for Atmospheric Turbulence in ideal Gaussian Beam.

There are two main components to the far-field intensity pattern: 1) a beam-wandering effect due to the tip/tilt phase contributions, and 2) a beam-intensity change due to the influence of higher order terms on the phase structure. These higher order terms resultsinto a larger beams, and in some cases to scintillation. The full effects of turbulence are shown in Fig. 5.

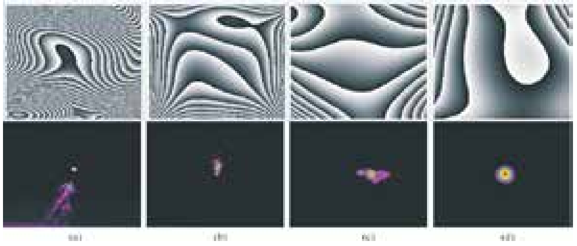

Fig. 5. Examples of turbulence phase screens (top row) in order of decreasing turbulence from (a) to (d), with the resulting (measured) laser beam intensity change shownbelow the respective screen.

Conclusion

The aim of the paper was to make a software for laser beam profiler to show the effect of atmospheric turbulence on the propagation of an Ideal Gaussian Beam with its variations in Intensity plot using MATLAB and Lab-VIEW Integration.

This work can help the scientist to analyse laser beam propagation in a turbulent atmosphere so that they can takes counter steps in modelling a laser to avoid such turbulence to have minimum divergence.

FUTURE SCOPE

In future different atmospheric turbulence effects can also be modelled graphically with the same approach as represented on different modes of a Gaussian beam or any other type of laser.

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