E12

Fine Structure of Near and Far Field Diode Laser Emission Diagram

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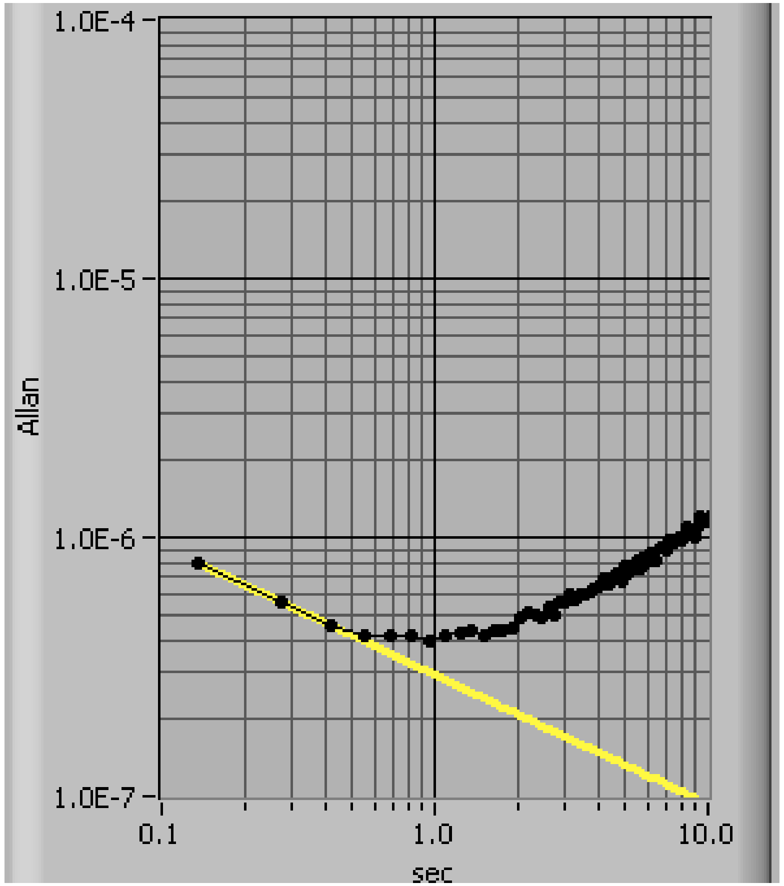
Abstract

Results of speckle noise investigation (see separate paper) show that additional noise in Diode Laser (DL) based system with topography reflector is formed on the reflector surface in presence of relative movement. Hence, origin of additional noise is due to fine structure of DL emission far field diagram. Examples of emission far and near field diagrams for different DL modules are presented. Presence of coherent DL emission on DL facet due to scattering in DL active area produces speckle pattern both in near and far fields. These patterns result in far field fine structure, DL "baseline", and additional noise.
Several DL modules were investigated including DL with single mode fiber output. Results obtained were analyzed with respect to DL module structure to determine origin of TDLS sensitivity limitations and ways of sensitivity improvement. As result fundamental limit of sensitivity due to DL quantum noise [1] was achieved both for traditional systems and DL based systems with topography reflector.

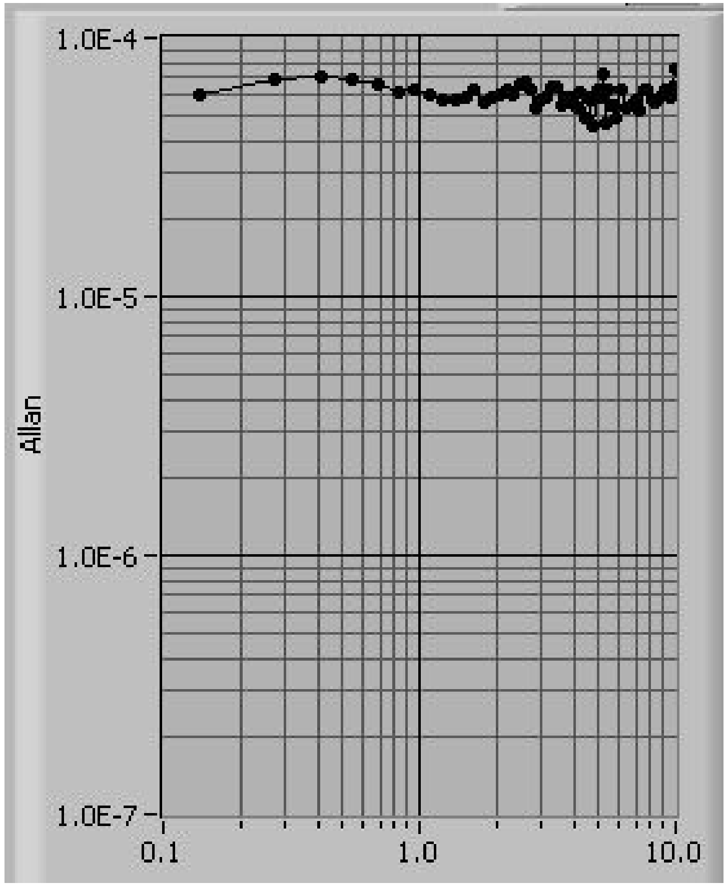
Reference:

[1] A.Nadezhdinskii, in TDLS 2005, Abstracts of papers, Florence, Italy, 2005, p.66.

Presence of additional noise



Examples of Allan plots of relative photo-current noise - Δi/i for traditional TDLS scheme (left) and system with topography reflector (right)



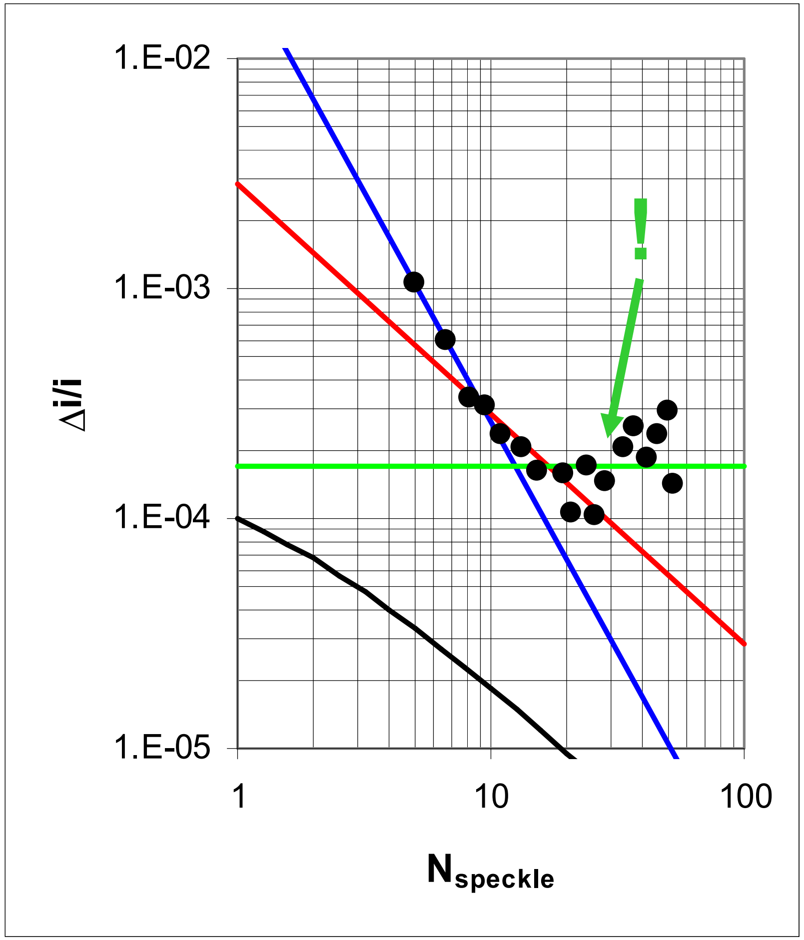
Conclusions:

1. Because of additional noise presence more than 2 orders of sensitivity were lost
2. Additional noise looks like flicker one

Goal: to identify the noise origin and to suppress it.

Experimental investigation of additional noise for DL based system with TR

Experimental setup

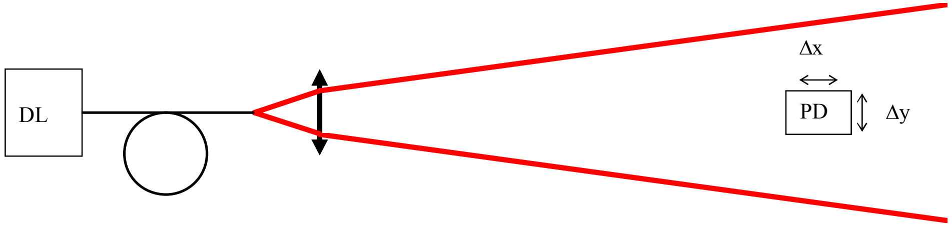


Relative photocurrent noise dependence on speckles number N in receiving aperture.

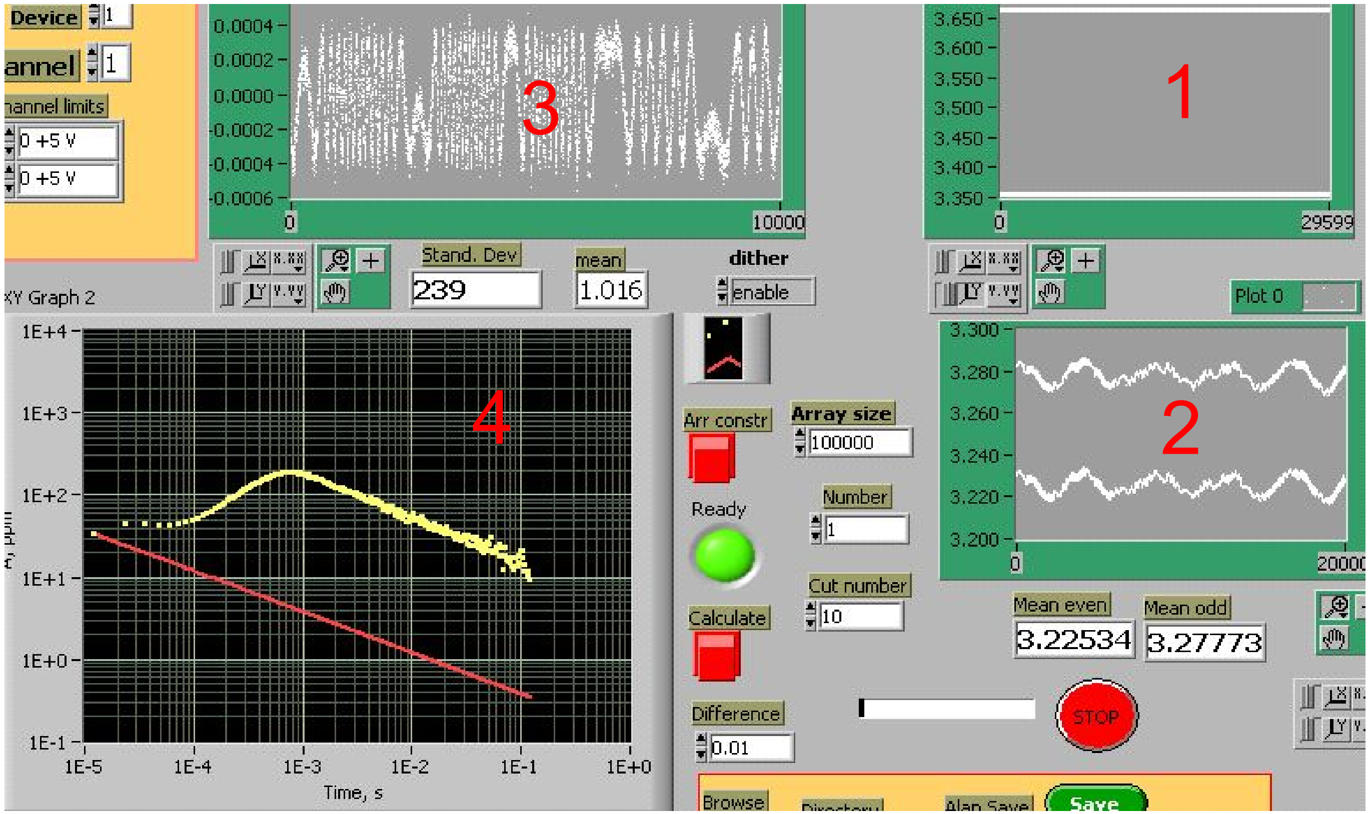
Speckle noise modeling prediction is shown by black line, blue line – thermal noise of preamplifier resistor, red line – photocurrent shot noise

Additional noise in DL based systems with TR does not depend on N. Hence, it is not due to speckle noise of DL light scattered by TR. This noise is forming on TR itself

Time dependence of additional noise



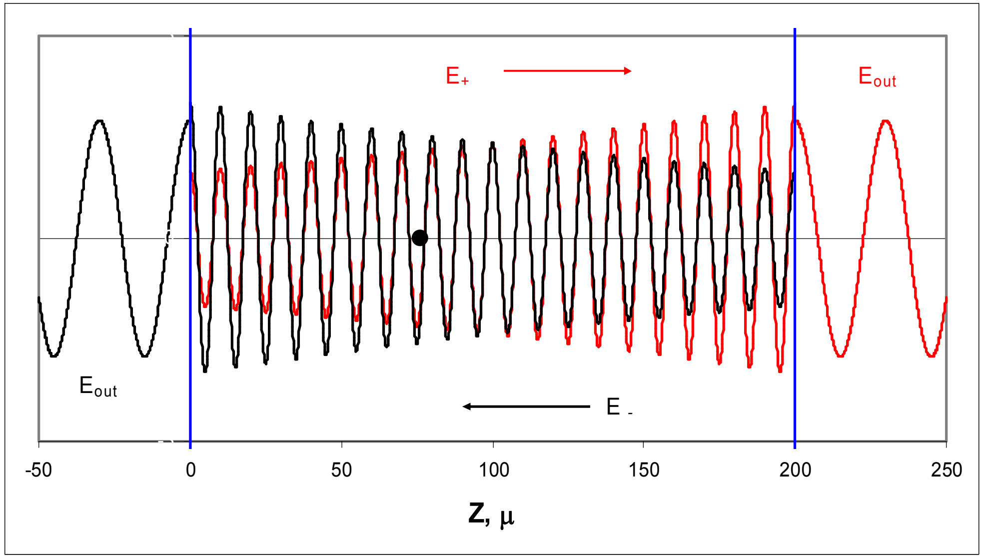
Scheme of experimental setup installed on office table. Vibration was initiated by operating ventilator



1. DL current
2. PD signal
3. EvenOdd ratio
4. Ratio Allan plot

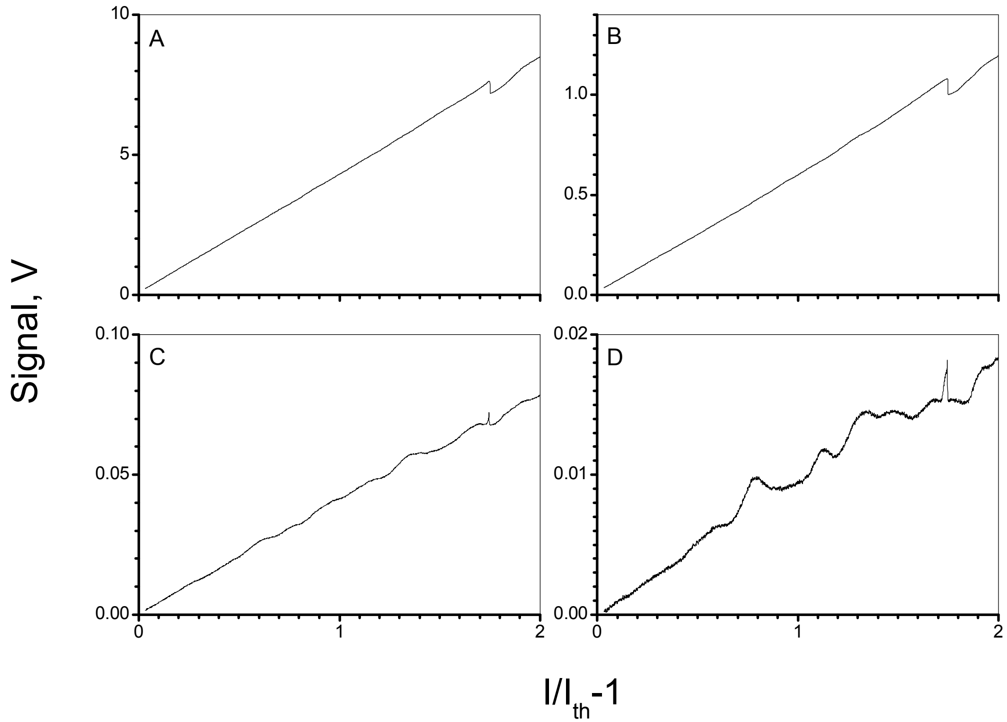
This behavior can be explained only if DL far field diagram has fine structure.

Baseline

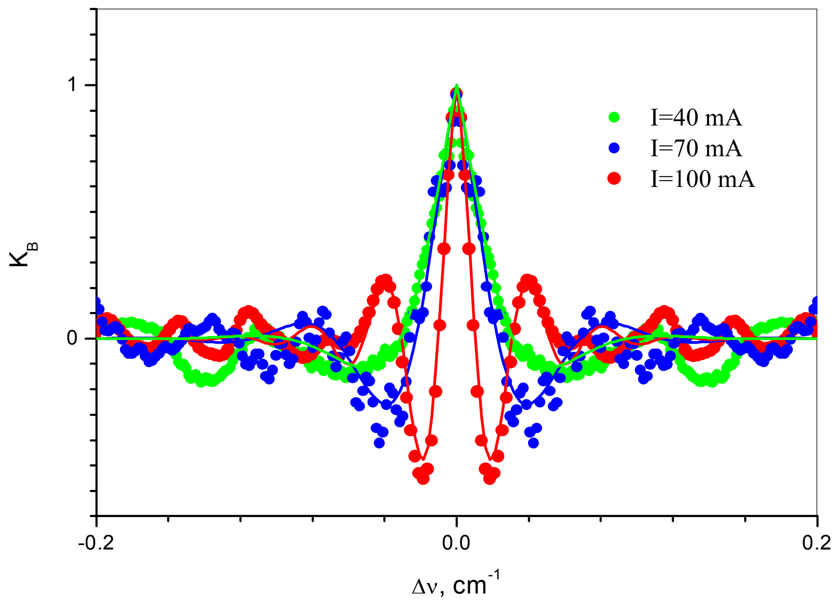


Interaction of standing wave with inhomogeneities in DL active area causes small variations of all DL radiation characteristics: intensity, frequency, near and far field, etc. (baseline)

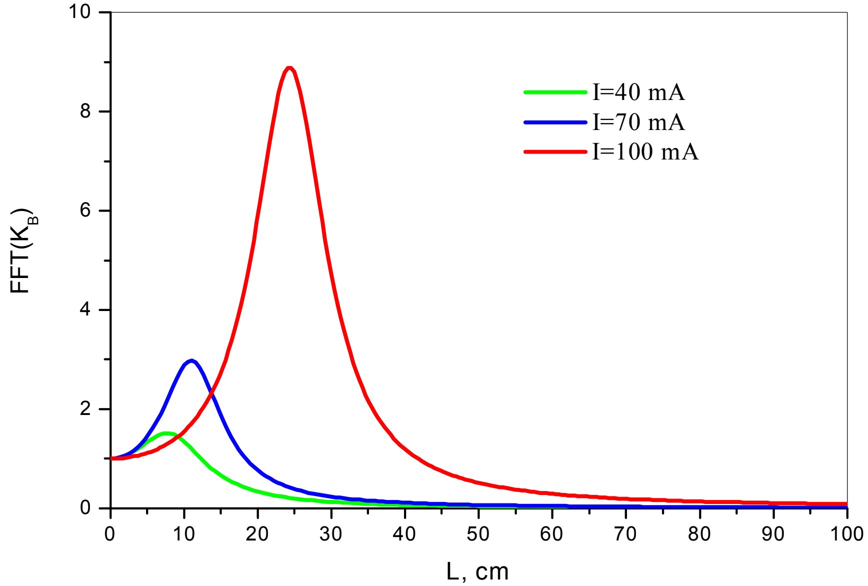
Spatial inhomogeneity of DL far field:
PD was installed in DL diagram center (A); then detector was moved in positions to have step-by-step 10 times smaller signal (B, C, D)



Baseline nature



Baseline correlation functions for several excitation currents

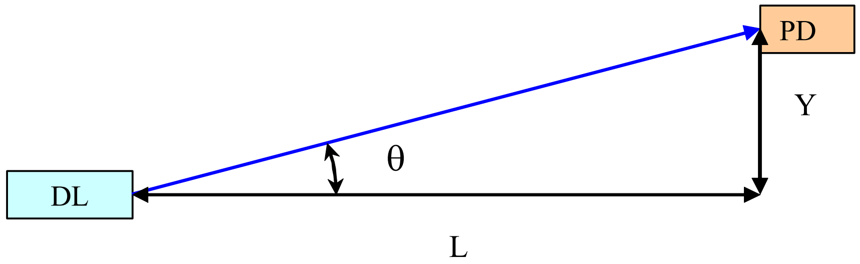


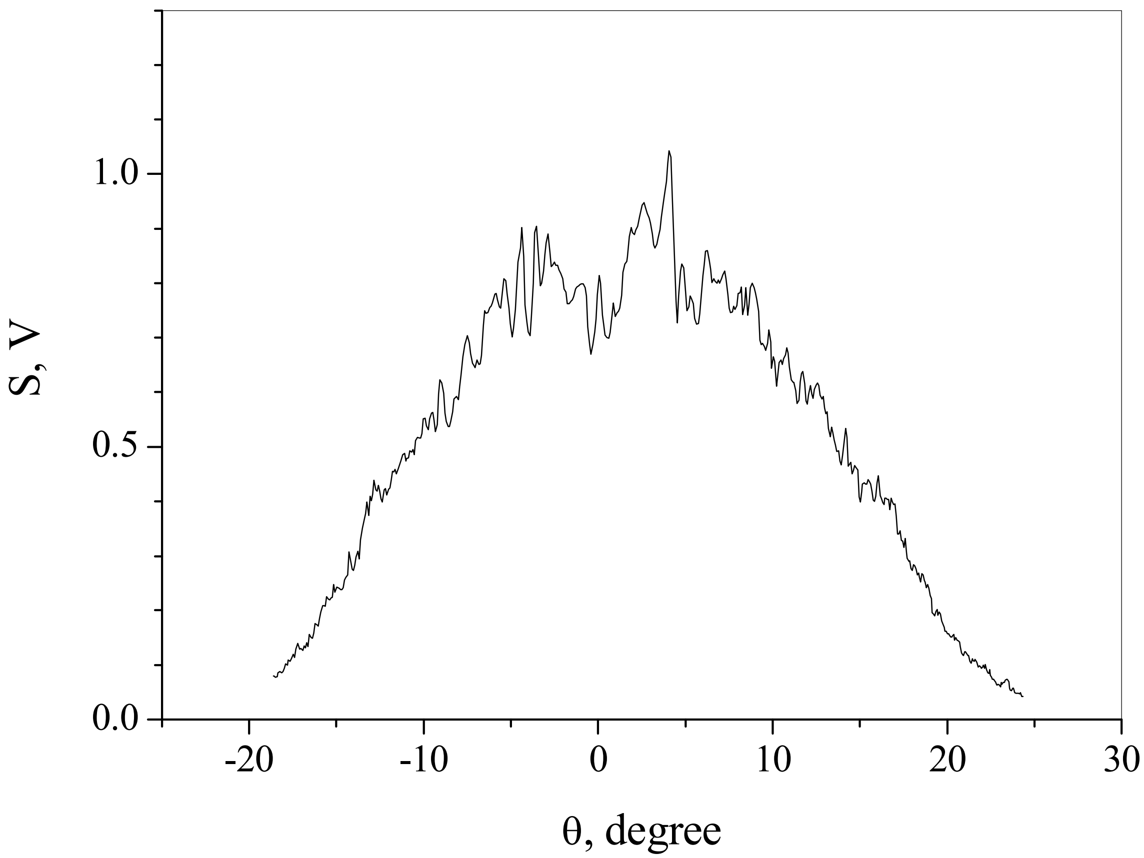
FFT of baseline correlation functions for several excitation currents (“relaxation oscillations”)

Conclusion: baseline nature is related to interaction of standing wave with inhomogeneities in DL active area and electrons diffusion. Above mention processes characteristics are determined by properties of electron-photon system of DL (relaxation oscillations)

Far field diagram of DL radiation

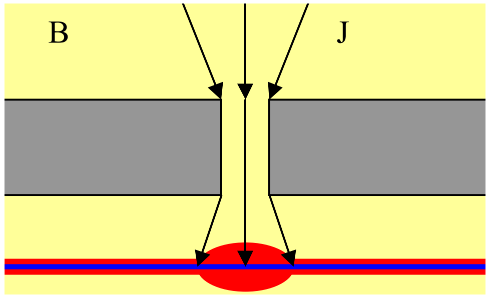
Block scheme of far field DL radiation diagram measurement

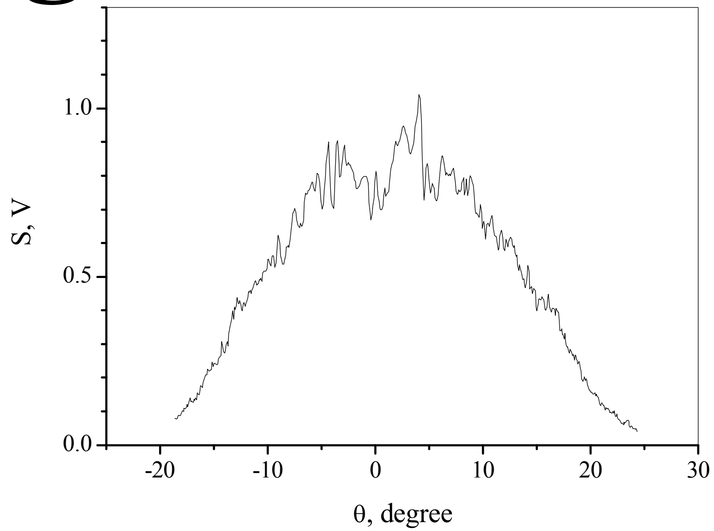




Example of fine structure of DL far field diagram (Laser Components)

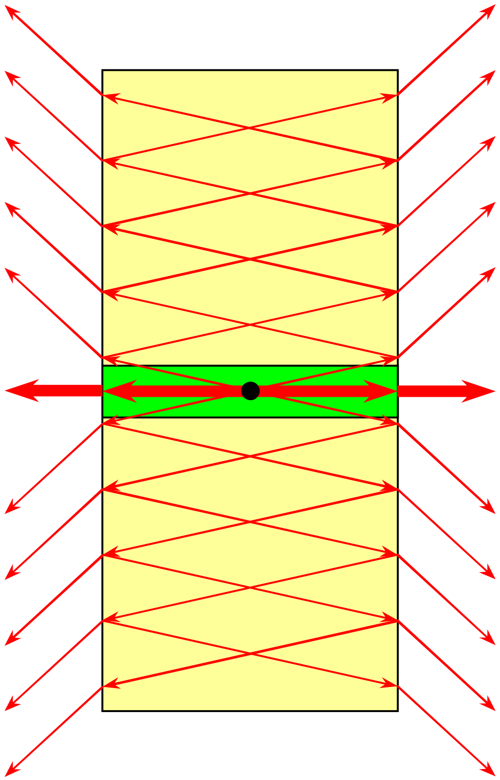
Scattering inside DL active area

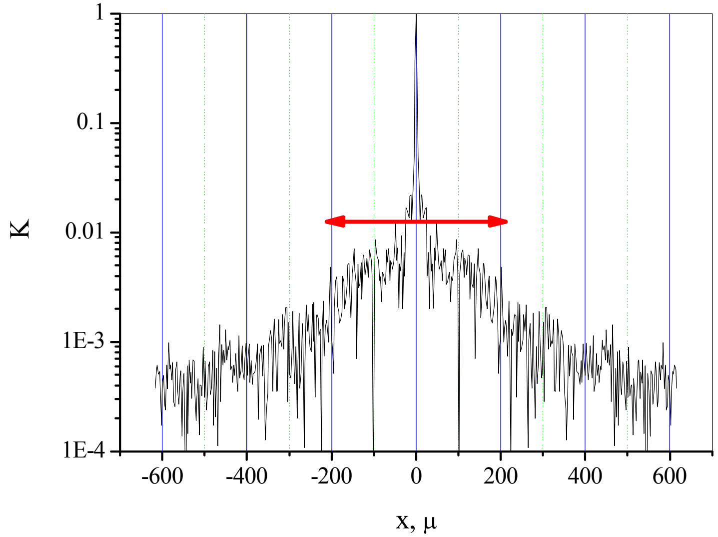




Far field diagram

Scattering on DL active area inhomogeneities



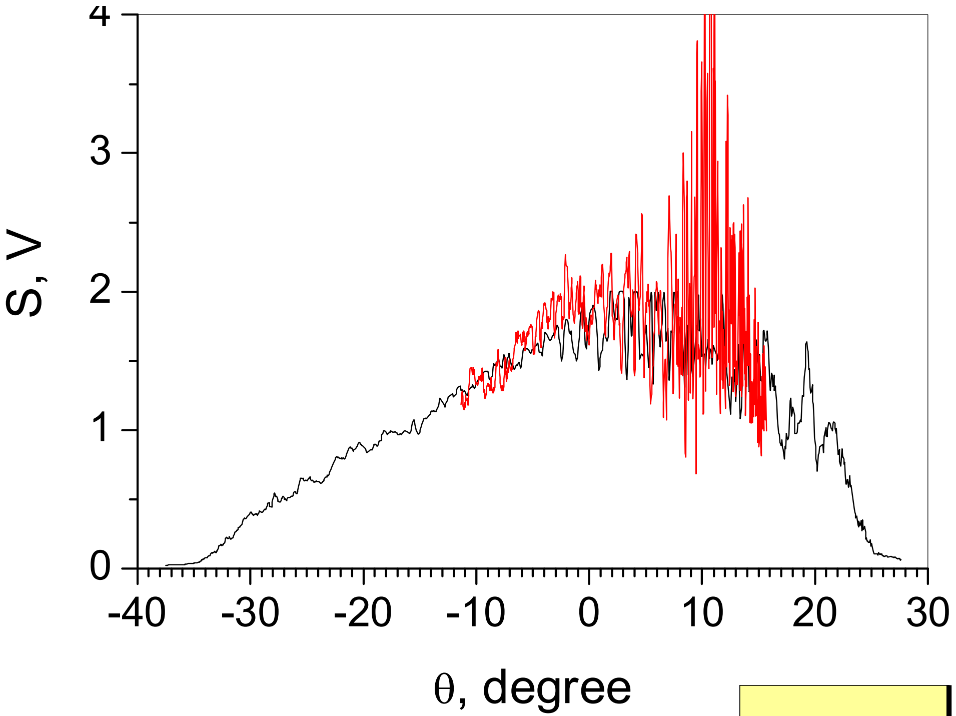


Near field diagram

Red arrow – DL dimension

Conclusion: light scattering on inhomogeneities in DL active area causes fine far field structure, baseline presence, and additional noise

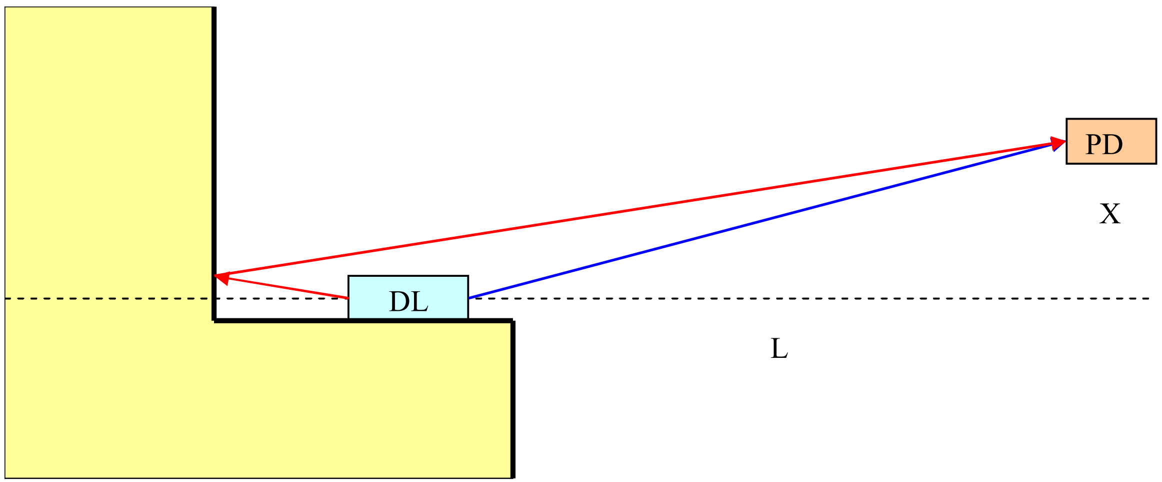
Scattering and reflection inside DL module



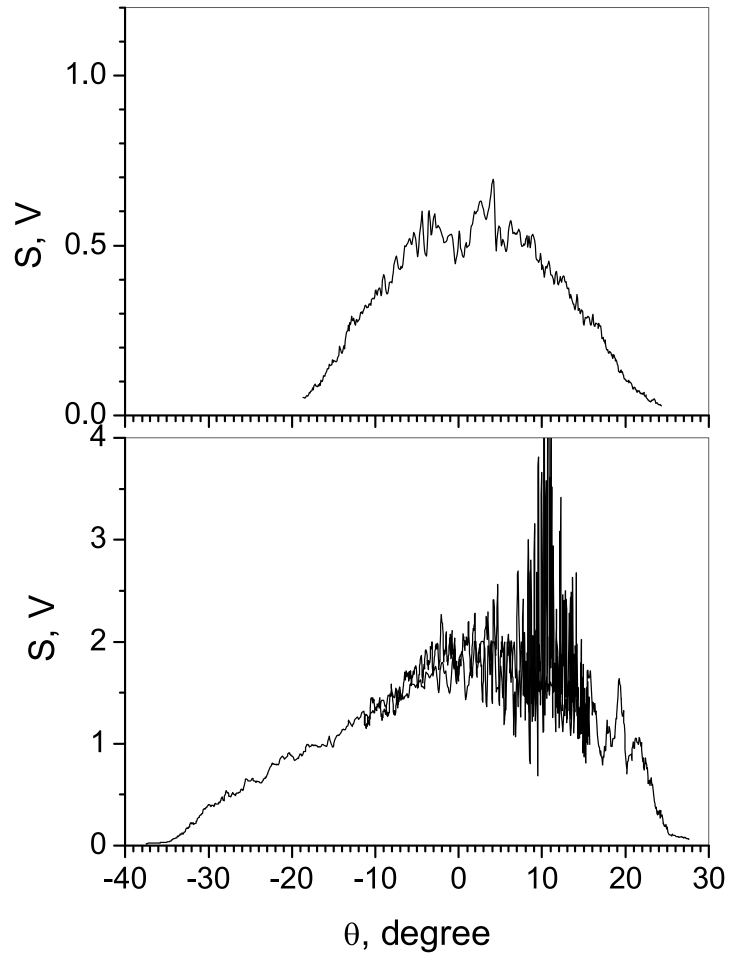
Fine structure of DL far field when reflection inside DL module takes place (Laser Components)

Scattering and reflection inside DL module causes fine far field structure, baseline presence, and additional noise

Scheme explaining formation of far field fine structure when reflection and scattering inside DL module take place

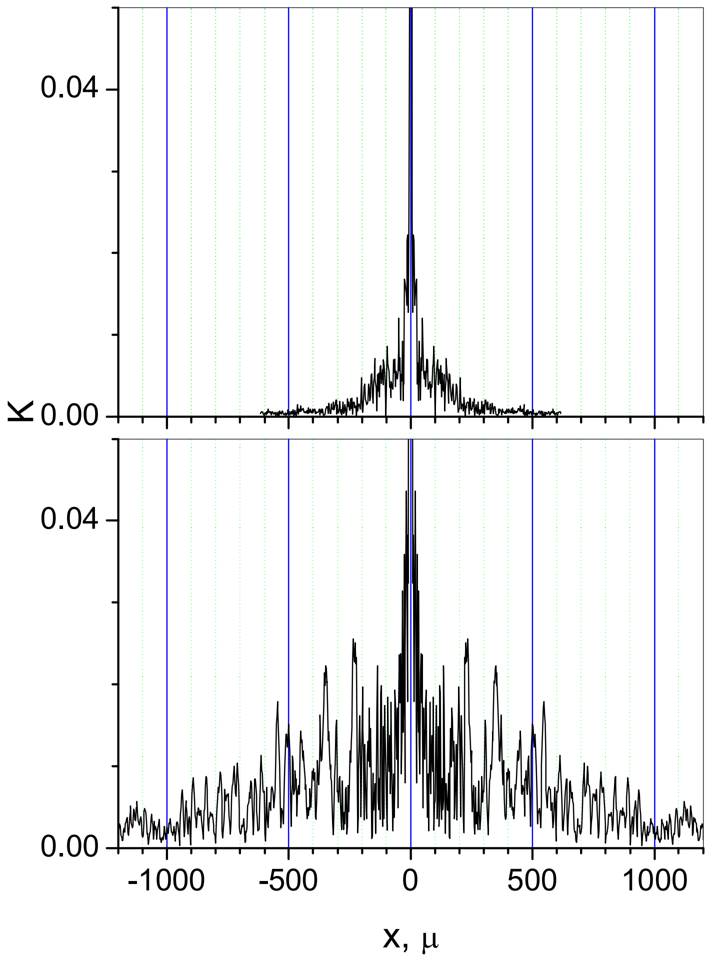


Near and far field diagrams



Far (left) and near (right) fields of DL radiation (Laser Components).

Upper and lower curves correspond to directions parallel and perpendicular to DL active area, respectively.



Conclusion: scattering and reflection inside DL module cause near field speckle pattern being origin of fine far field structure, baseline presence, and additional noise.

Speckle pattern of DL emission

Following mechanisms were considered:

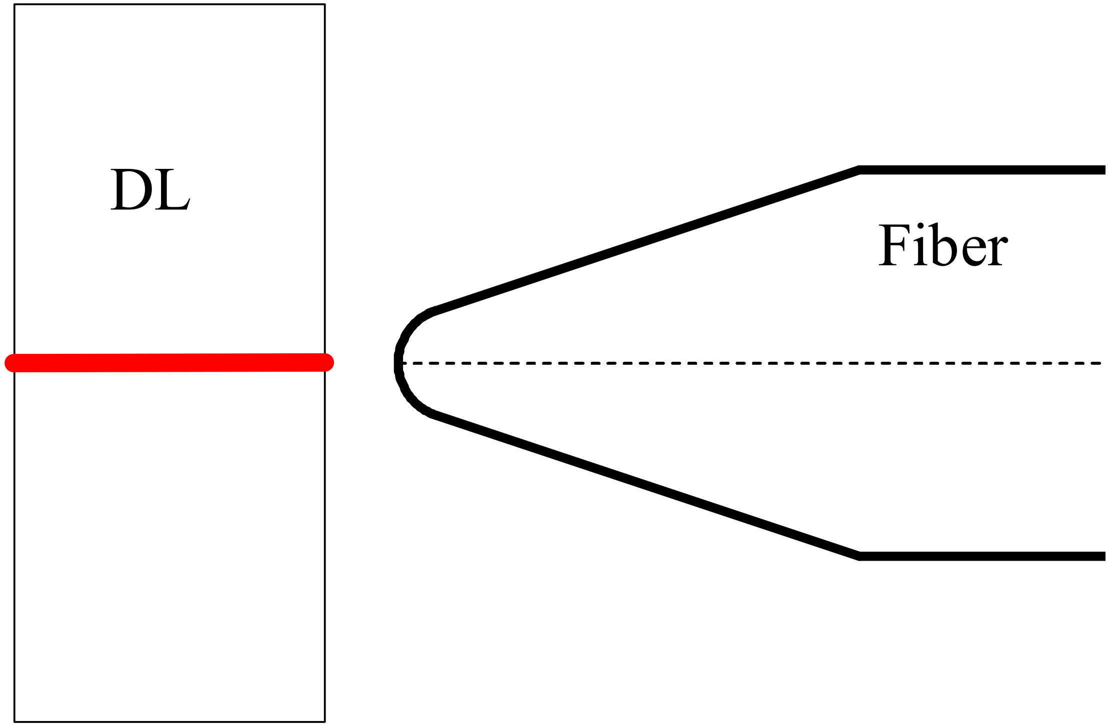
1. Interaction of standing wave with longitudinal inhomogeneities in DL active area
2. Interaction of standing wave with transverse inhomogeneities in DL active area
3. Light scattering on inhomogeneities in DL active area
4. Scattering and reflection inside DL module

All mechanisms under consideration form some sort of speckle pattern of DL emission and lead to:

A. Baseline presence
B. Spatial inhomogeneity of DL far field
C. Fine structure of DL far field
D. Additional noise if relative elements motion takes place in DL based system

The most dangerous are mechanisms # 3 and 4. For mechanisms # 1 and 2 suppression methods were developed

DL with single-mode fiber

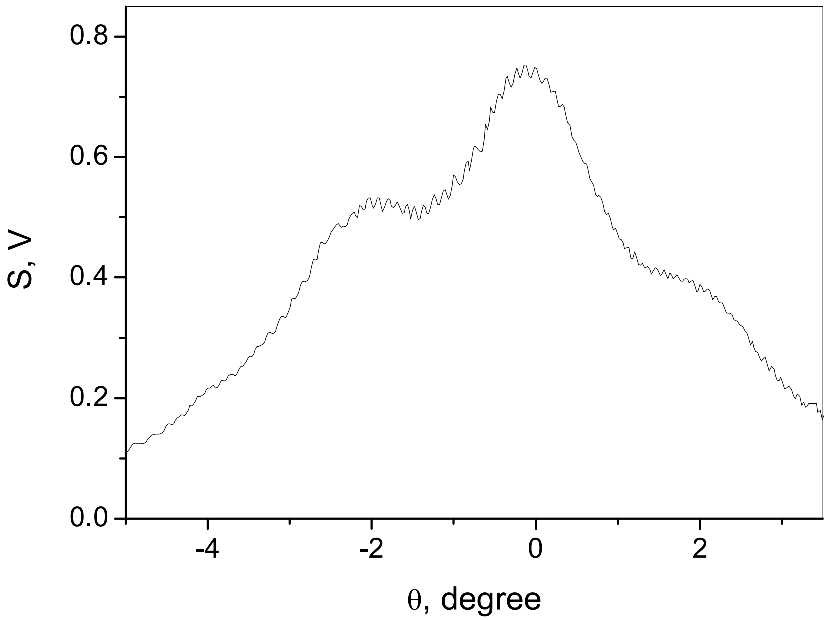


Scheme of single-mode fiber with micro-lens connection to DL. Presence of micro-lens allows one to collect radiation only from DL active area.

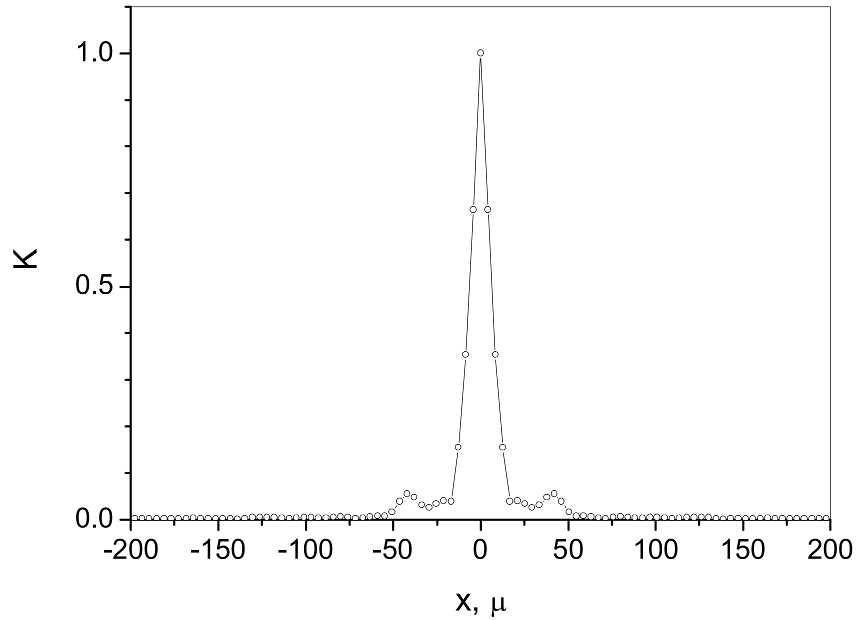
Hence, usage of DL with single-mode fiber is effective way to suppress role of light scattering inside DL chip and DL module

Speckle pattern of pig-tailed DL

Usage of pig-tailed DL is effective way to suppress role of light scattering inside DL chip and DL module



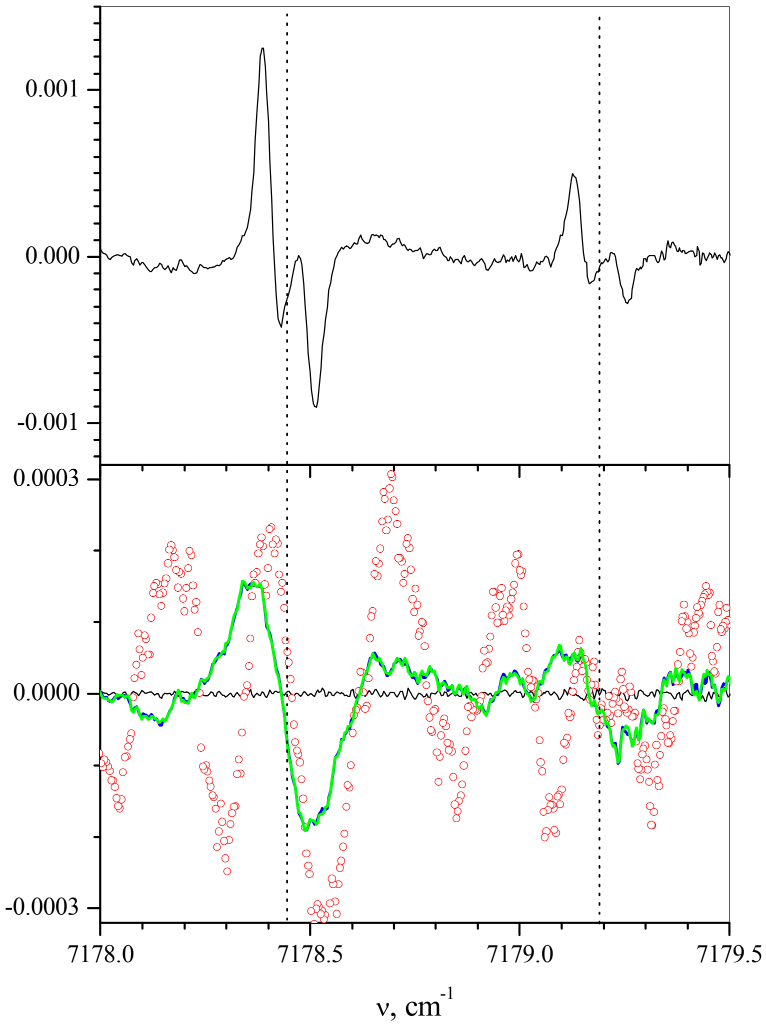
Far field fine structure of pig-tailed DL emission



Near field fine structure of pig-tailed DL emission

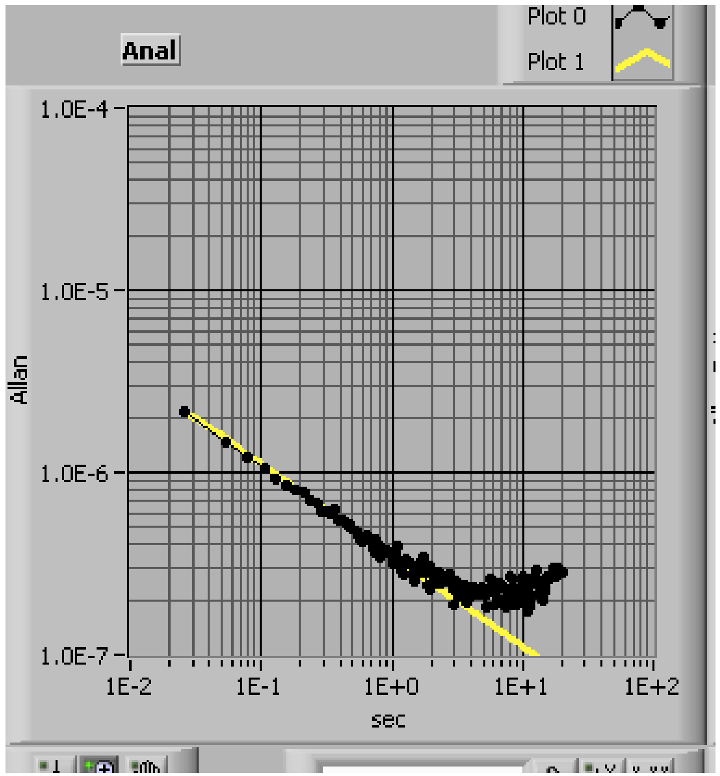
However, scattering inside single-mode fiber forms near field speckle pattern on fiber output facet being origin of fine far field structure, baseline presence, and additional noise. The problem can be solved with high quality fibers.

Conclusion



Baseline (open red circles) and its suppression (green curve). Small water lines are detectable.

Baseline and additional noise suppression



Absence of additional noise in system with topography reflector

If physical origin of baseline and additional noise is known their influence can be suppressed