# DIODE LASER FREQUENCY TUNING CYCLES STABILIZATION AT kHz LEVEL

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Diode Laser (DL) frequency stability is important for many DL applications. In [Yu.Kosichkin, A.Kuznetsov, A.Nadezhdinskii, A.Perov, E.Stepanov, Sov.J.Quantum Electronics, 12, 518 (1982)] DL frequency cycles stabilization was proposed. It combined DL frequency tuning with tuning cycles stabilization. Now this approach is widely used in our experiments as well as by several other groups.

In present paper new approach of this technique application is considered. Stability of diode laser frequency tuning cycles at **kHz** level was experimentally achieved. Physical origin of limiting mechanism is related to diode laser frequency quantum noise. Results obtained are compared with literature ones.

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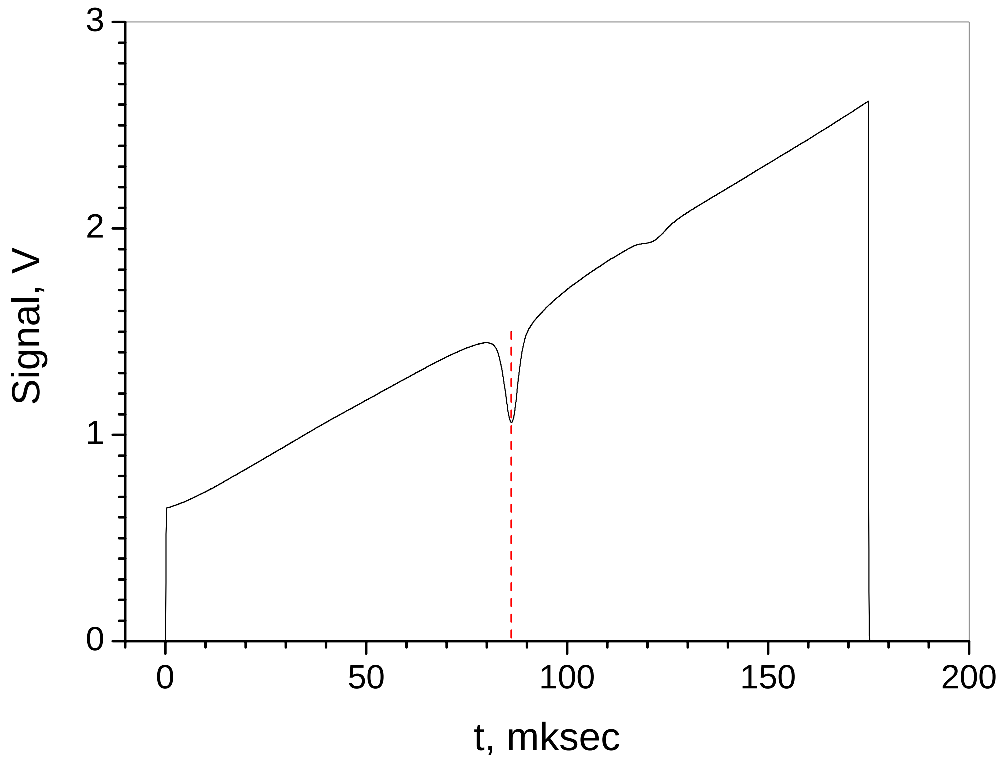
In present paper new approach of this technique application is considered. Stability of diode laser frequency tuning cycles at **kHz** level was experimentally achieved. Physical origin of limiting mechanism is related to diode laser frequency quantum noise. Results obtained are compared with literature ones.

# Frequency tuning cycles stabilization using reference spectral line

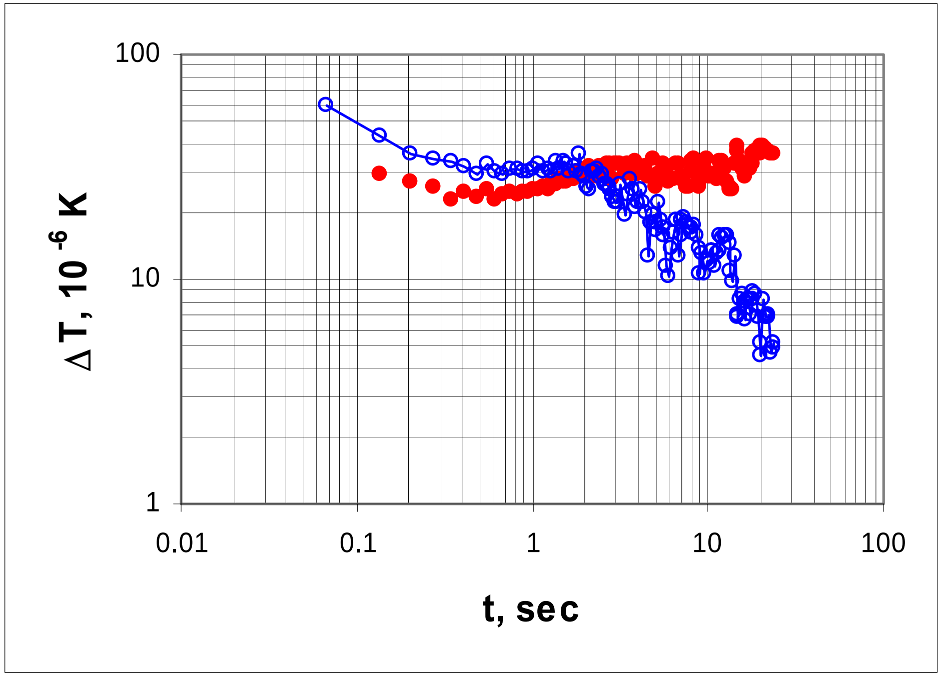



Signal waveform recorded by photo-diode, laser beam passed through cell with low pressure water vapor.

Temperature instability and diode laser frequency flicker noise resulted in spectral line position variations. This fact can be used as measure of diode laser frequency stability.

This approach was used for the first time in: Yu.Kosichkin, A.Kuznetsov, A.Nadezhdinskii, A.Perov, E.Stepanov, Sov.J.Quantum Electronics, 12, 518 (1982); I.Zasavitskii, A.Kuznetsov, Yu.Kosichkin, P.Krukov, A Nadezhdinskii, A.Perov, E.Stepanov, A.Shotov, Sov.Tech.Phys.Lett., 8, 502 (1982)

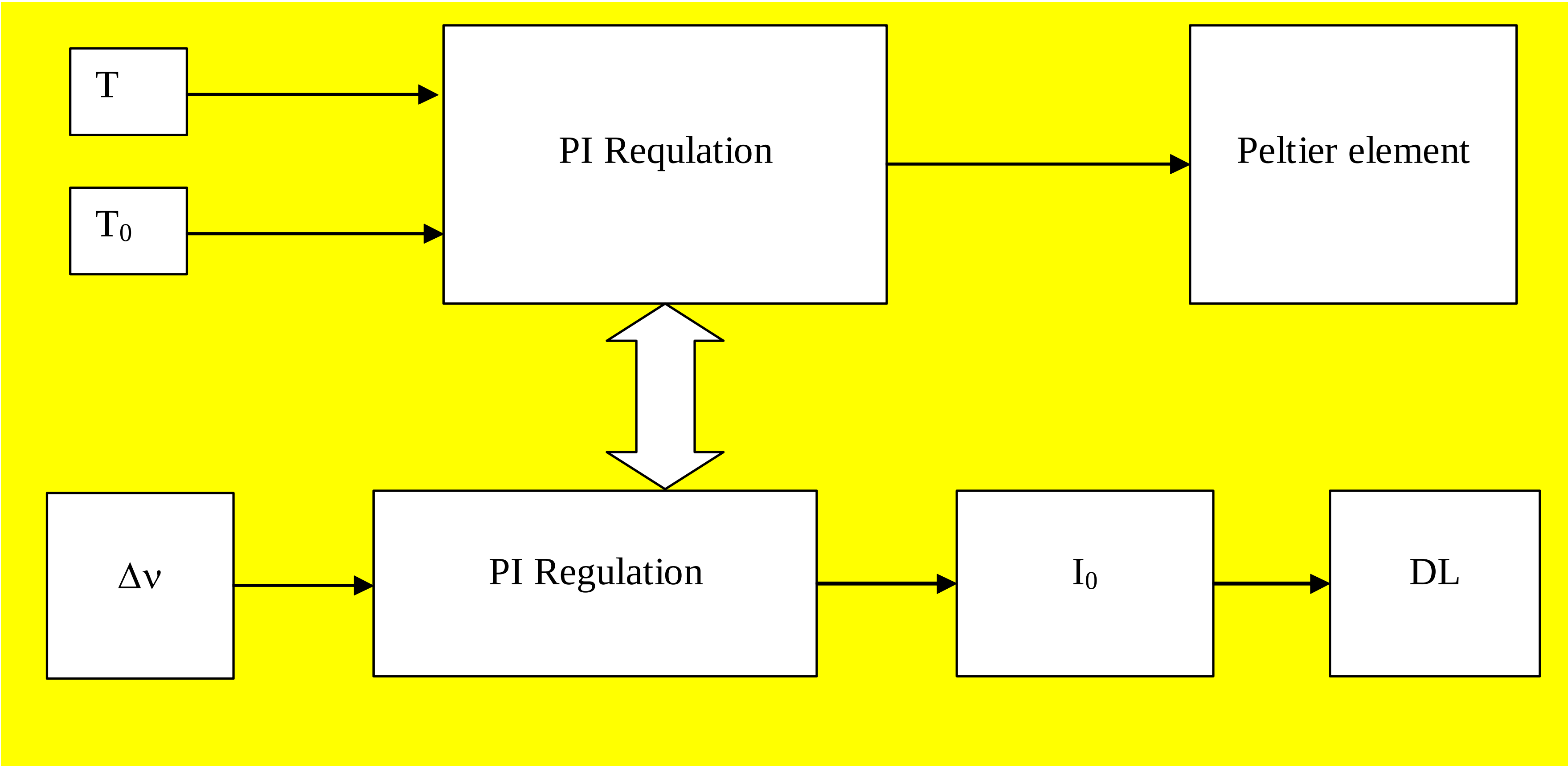
# Temperature and DL frequency instability




For different DL application its frequency stability plays key role. Because of DL frequency temperature dependence spectral line can be used as temperature sensor. Modified software was able to analyze simultaneously temperature variations measured by termistor and with help of reference spectral line. For this purpose DL temperature tuning coefficient was determined independently.

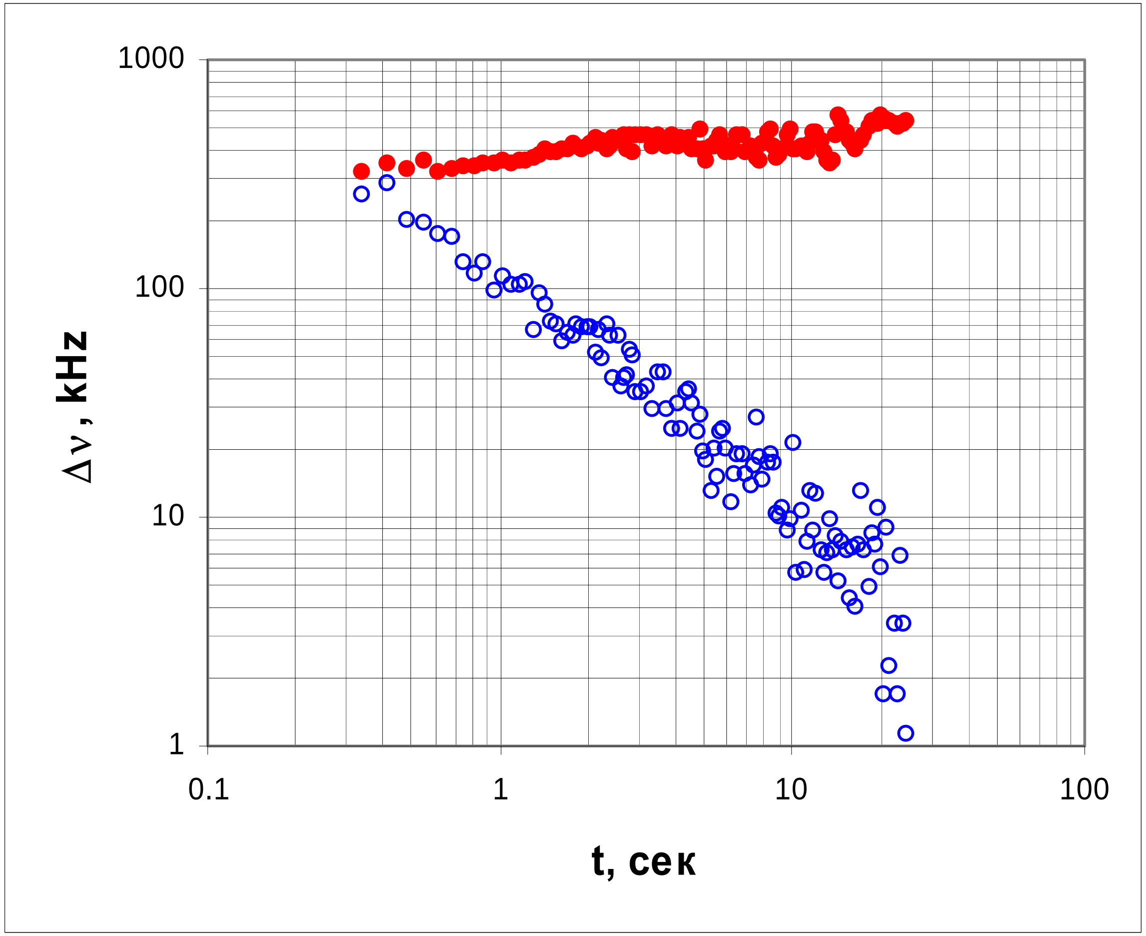
Allan plot of instability of temperature measured by termistor (blue open cycles) and with help of reference spectral line (red solid cycles) as function of averaging time t. Diode laser temperature stability at 0.03 mK level was achieved (see separate poster). Above mentioned value corresponds to 450 kHz frequency stability.

# Block-scheme of frequency tuning cycles stabilization




Both temperature stabilization and frequency tuning cycles stabilization are using in our experiment with some regulation between these two loops.

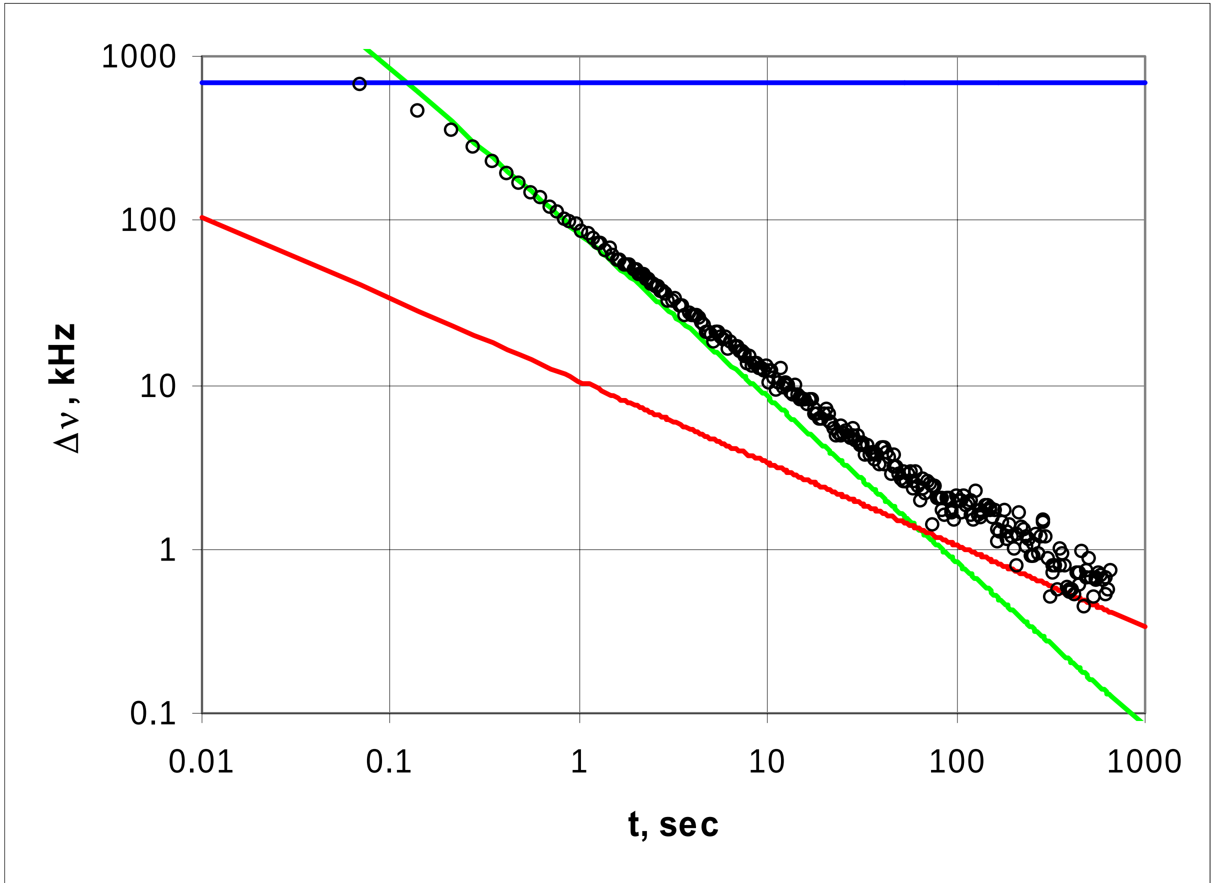
# Frequency tuning cycles stabilization




Allan plot of DL frequency instability as measured using reference spectral line; only temperature stabilization is on (red solid cycles); DL frequency tuning cycles stabilization is on (blue open cycles)

Example of system operation. When frequency tuning cycles stabilization is off temperature instability broad maximum and DL frequency flicker noise can be observed. With frequency tuning cycles stabilization on - significant improvement of frequency stability takes place.

# Operation of frequency tuning cycles stabilization




Allan plot of DL frequency instability with frequency tuning cycles stabilization on (black cycles) and main mechanisms that determine system operation.

**DL quantum noise limited frequency stabilization at kHz level was experimentally demonstrated.**

Blue line – DL frequency flicker noise due to excitation current density fluctuation.
Green line – noise reduction due to frequency tuning cycles stabilization.
Red line – DL frequency quantum noise (see separate poster).

# Comparison with traditional approach of DL frequency stabilization

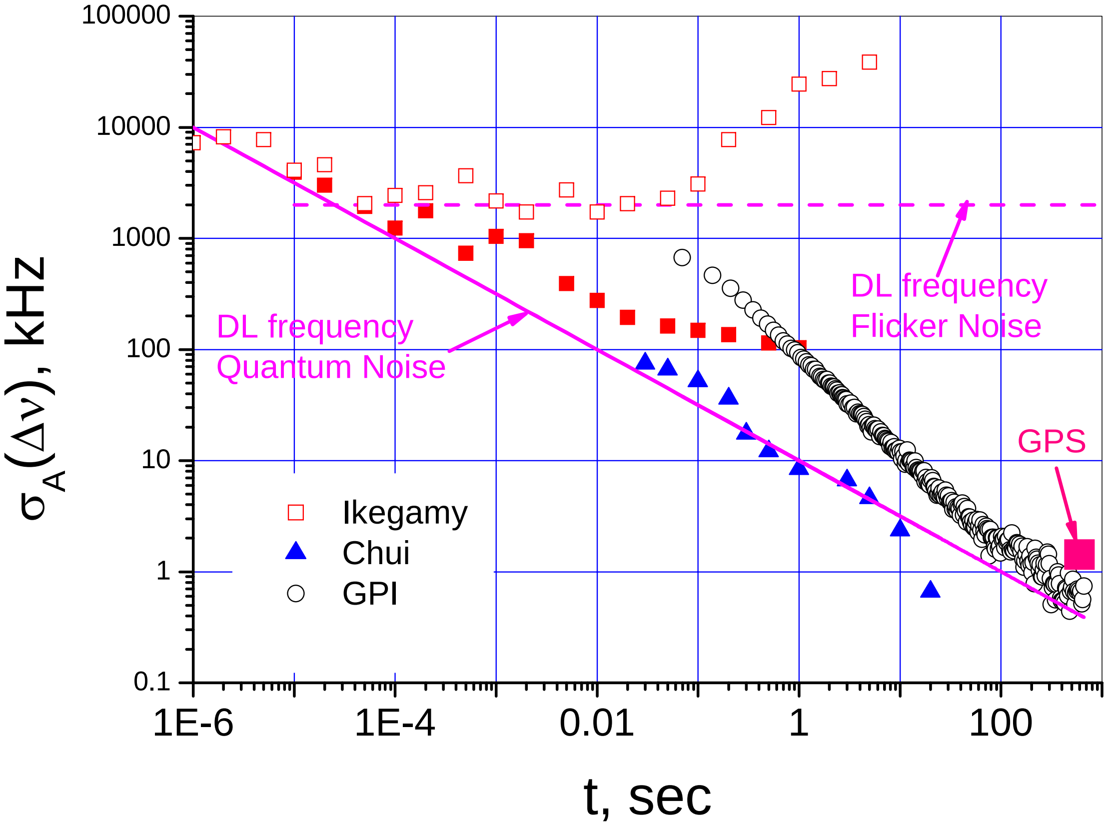
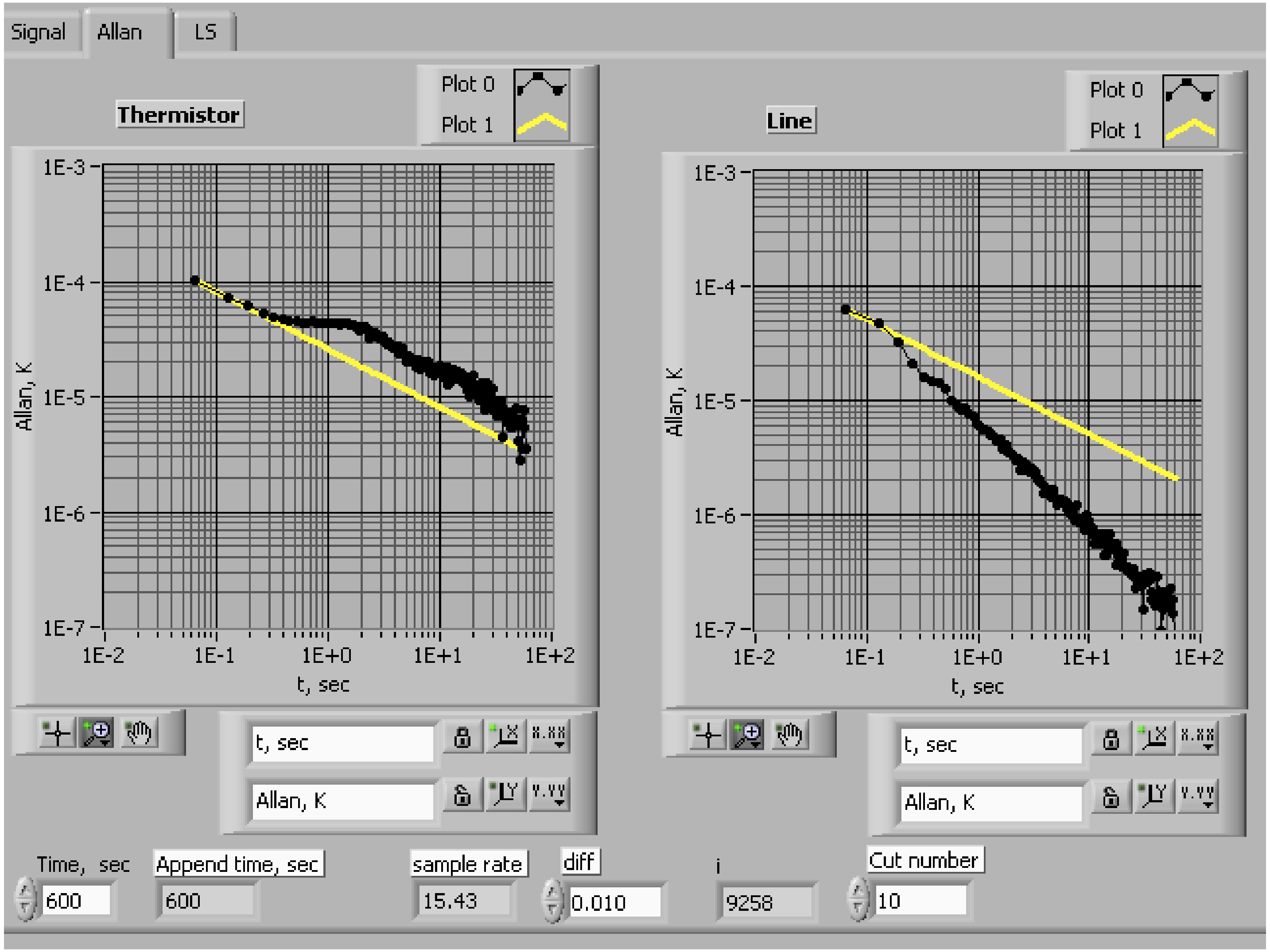



Fig. shows Allan deviation of DL frequency demonstrating kHz stability close to needs of Global Position System (GPS). In present case spectral line of water vapor at low pressure (WHH ~ 600 MHz) was used for stabilization.

Comparison with experiments of traditional frequency stabilization are presented. Dominating noise mechanisms such as DL frequency quantum noise and flicker noise due to excitation current density fluctuations are considered.

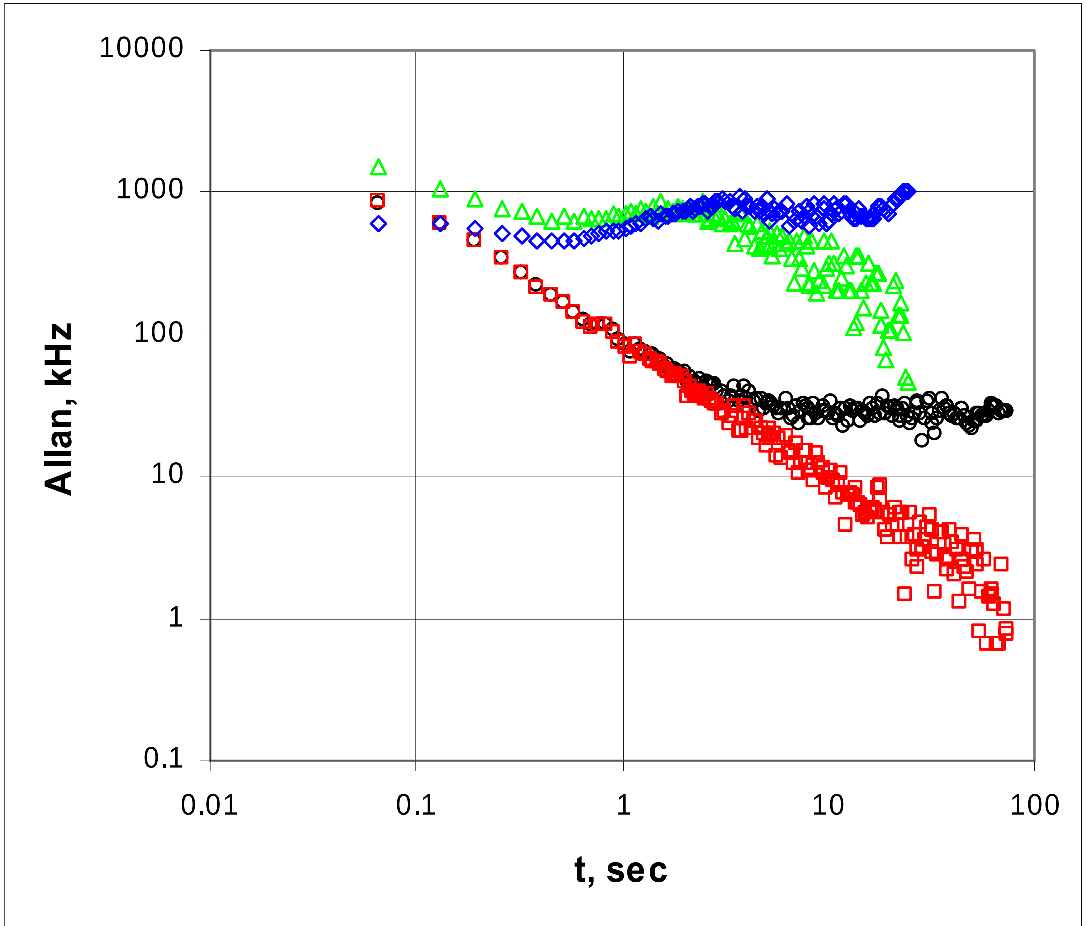
# LineStabilization software




Special software (LineStabilization) was developed for simultaneous measurement and analyses of signals in any two channels.

Allan plot of temperature as measured by termistor (left) and using spectral line (right). Both temperature stabilization and frequency tuning cycles stabilization are on.

# Check of stabilization quality




Pronounced difference between two channels is due to diode laser beam inhomogeneity

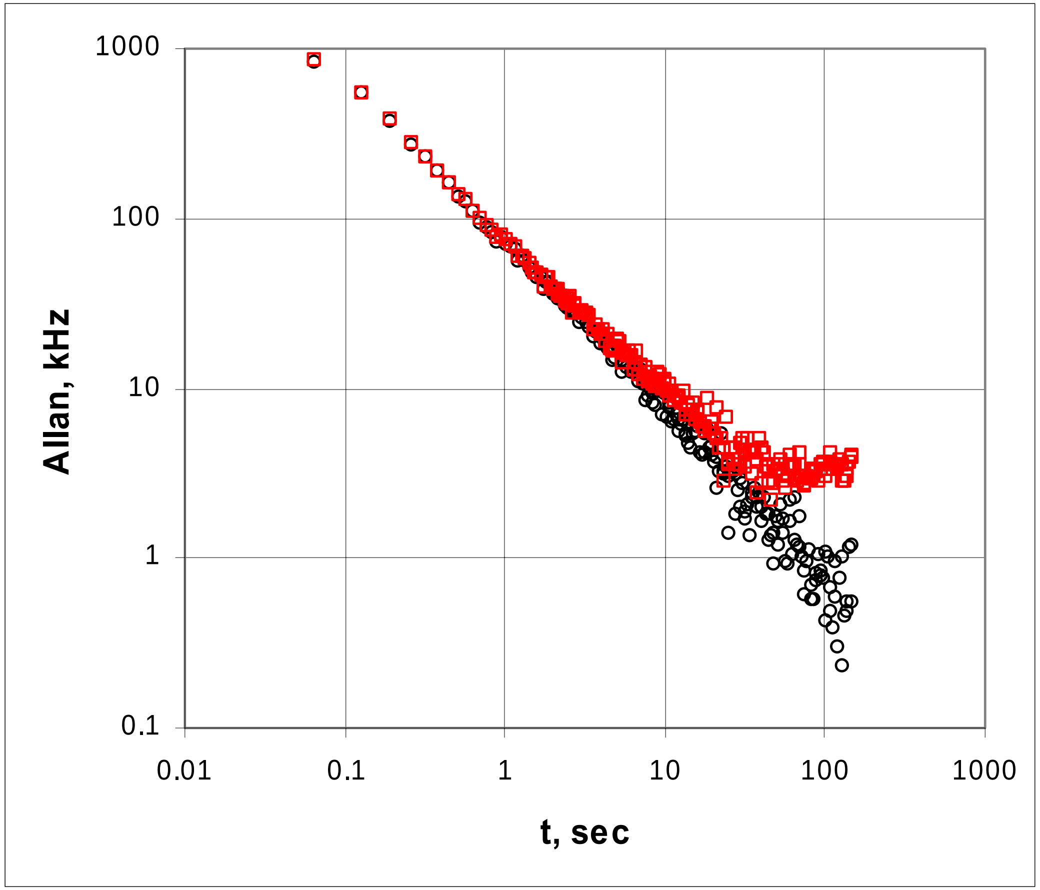
Developed software (LineStabilization) enable us to investigate quality of stabilization when two different channels were simultaneously measured.

Frequency instability as measured by termistor (green triangles) and spectral line (blue rhombs) when line stabilization was off.

Frequency instability measured in two different channels of our instrument; line stabilization was on. Reference channel (red squares) was used for stabilization. Part of laser beam was directed to analytical channel used to control stabilization quality (black cycles).

# Check of stabilization quality

## Experiment with homogeneous laser beam




Frequency instability measured in two different channels of our instrument; frequency tuning cycles  stabilization was on.

Reference channel (black cycles) was used for stabilization. Radiation reflected its detector was focused one photo detector of analytical channel to control stabilization quality (red squares).

Significant improvement is obvious. Difference between channels for high averaging times can be explained by small laser beam inhomogeneity.

# Conclusion

**Diode laser frequency tuning cycles stabilization using reference spectral line was used to improve frequency stability.**

**Achieved frequency stability at kHz level is limited by fundamental process – diode laser frequency quantum noise.**

**Approach under consideration and stability obtained open new possibilities for accurate line shape measurements.**

**This approach can be interesting for some other applications: secondary frequency standards, GPS, WDM, etc.**