Frequency tuning of fiber pigtail diode laser

DLS LAB

A.Nadezhdinskii

A. M. Prokhorov General Physics Institute of RAS, 38 Vavilov str., 119991, Moscow, Russia, E-mail: Nad@nsc.gpi.ru

Introduction

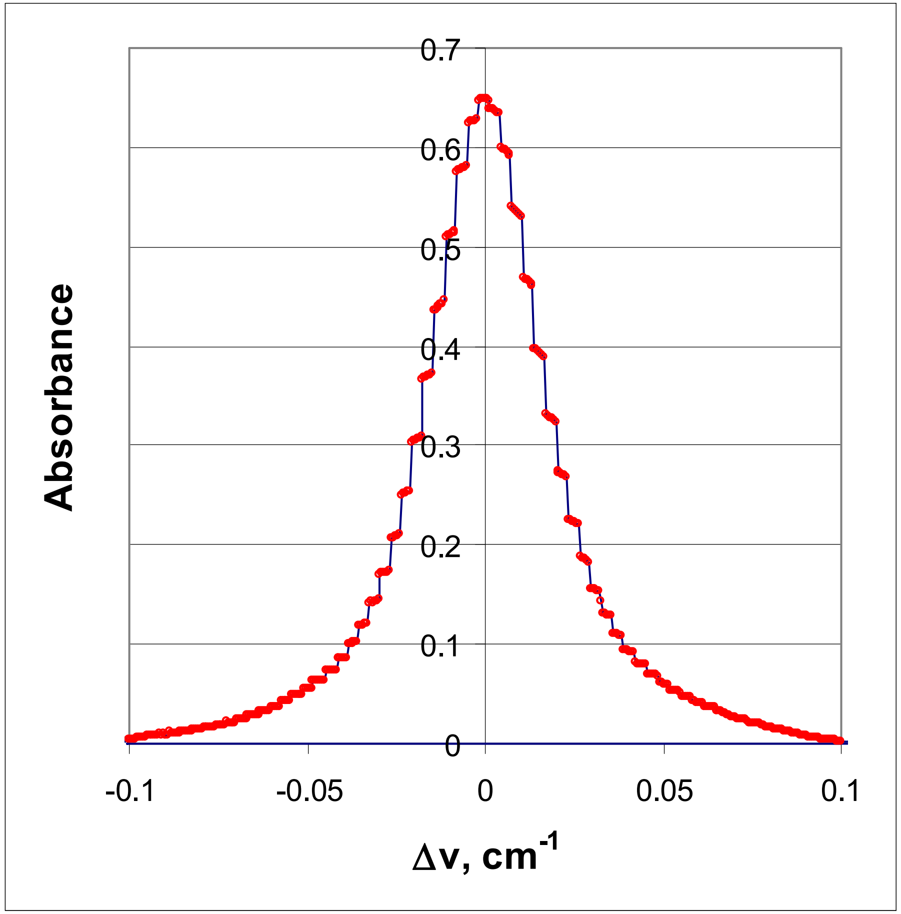
Baseline is determined TDLS limit for trace molecular absorption detection.
Baseline nature is due to interaction of DL standing wave with in-homogeneities inside DL itself and optical scheme based on DL. At the moment 8 baseline mechanisms were identified [1]:

B1 – DL active area conductivity in-homogeneity.
B2 – Excitation current density fluctuations.
B3 – Light scattering inside DL active area.
B4 – Light scattering inside DL module.
B5 – Fiber leakage modes.
B6 – Optical feedback.
B7 – Interference due to reflection and scattering in optical scheme.
B8 – Scattering inside fiber.

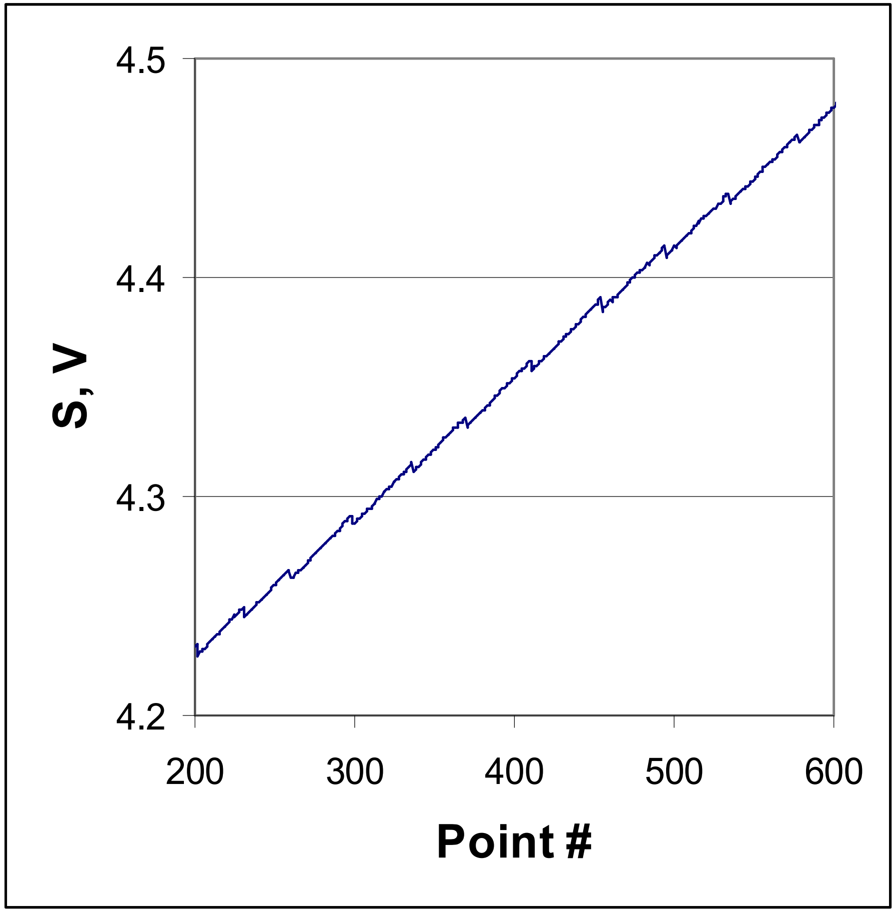
In present paper B6 – Optical feedback will be considered.

[1] Alexander Nadezhdinskii, Baseline in TDLS: investigation and suppression, in "Abstracts of papers of 7th International conference on Tunable Diode Laser Spectroscopy", Zermatt, Switzerland, 2009, p.75.

B6 – optical feedback



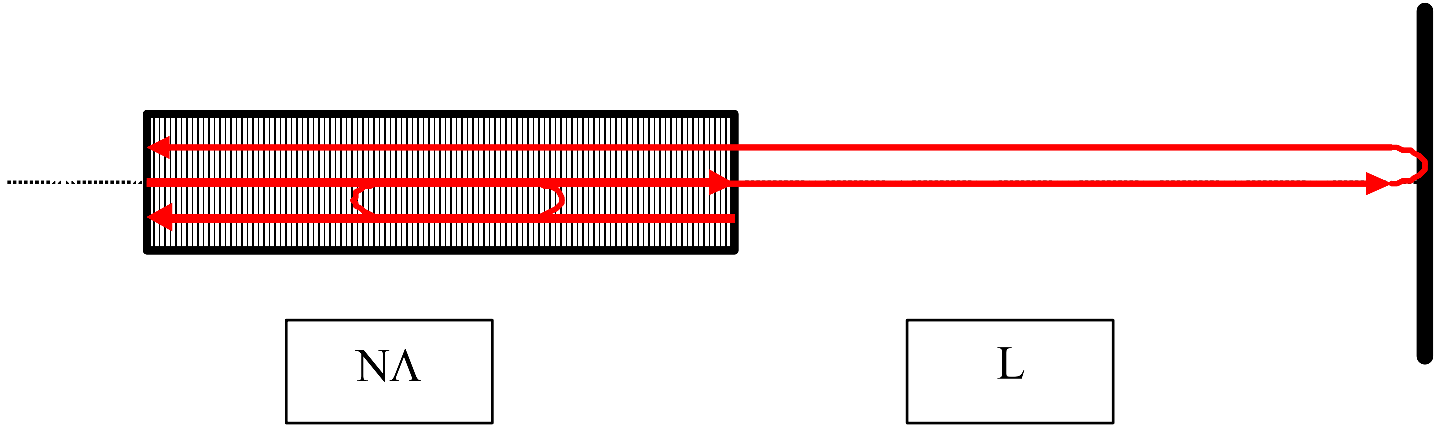
Water vapor line recorded using DL with significant optical feedback.



B6 baseline due to optical feedback.

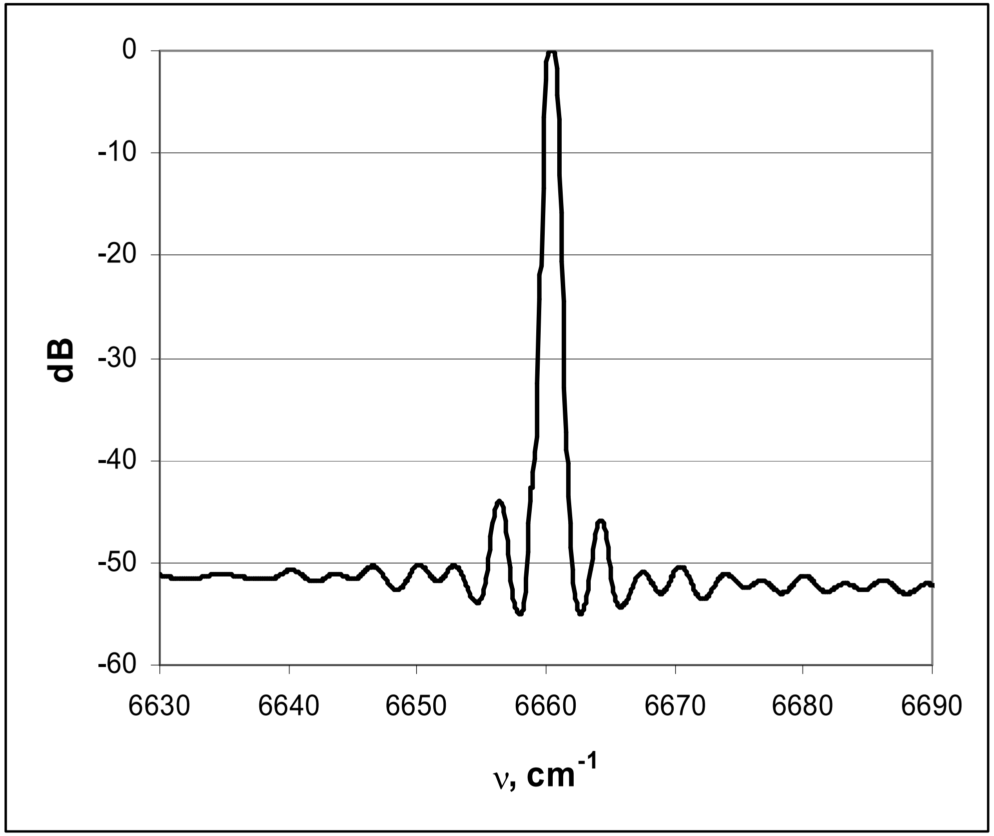
Optical feedback formation in DL

Optical feedback plays key role in laser generation. In recent DL optical feedback if formed due to DFB resonator. If part of reflected or scattered DLlight is coming back to DL active area parasite optical feedback can take place.



Optical feedback formation in DFB DL with fiber output; NΛ - DL resonator length, Λ and N – DFB period and its number, respectively, L – fiber length.

Optical feedback due to DFB

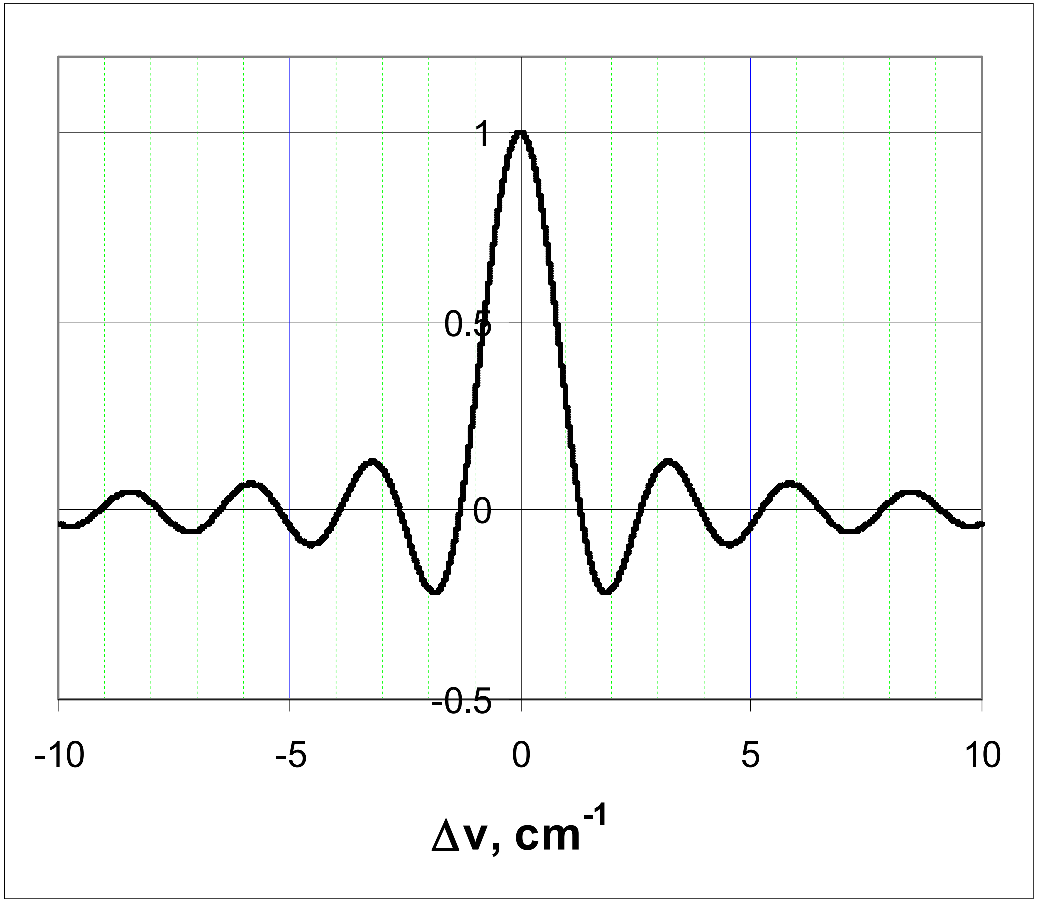


Spectrum of one of the DL under investigation.

DFB optical feedback

$$\frac{E}{E_0 4kN} = \left\{ \frac{\sin[8\pi n(\nu - \nu_0)\Lambda N]}{8\pi n(\nu - \nu_0)\Lambda N} \right\}$$

Normalized DFB optical feedback

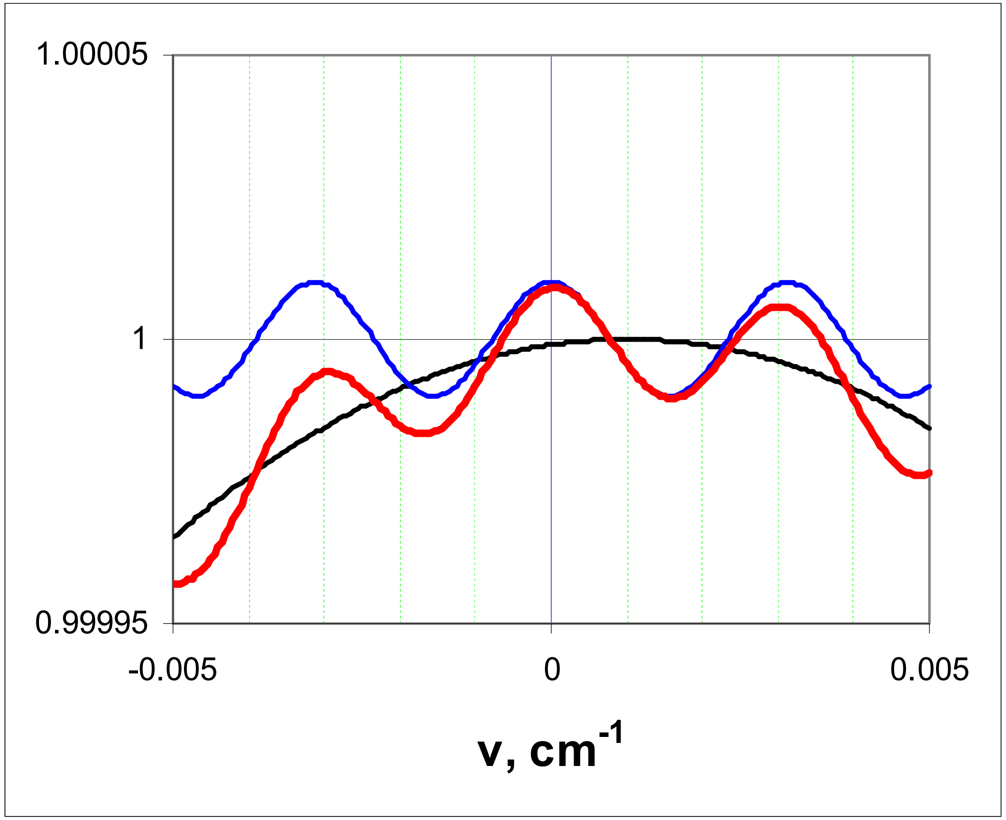


Optical feedback

{ } DFB optical feedback (black curve in figure)

$$\frac{E}{4kNE_0} = \left\{1 - \frac{\left[8\pi n(\nu - \nu_0)\Lambda N\right]^2}{6}\right\} + \beta \cos\left[4\pi\nu L\right]$$

L – fiber length; β - DL radiation part achieving DL active area after reflection from fiber end (blue curve).



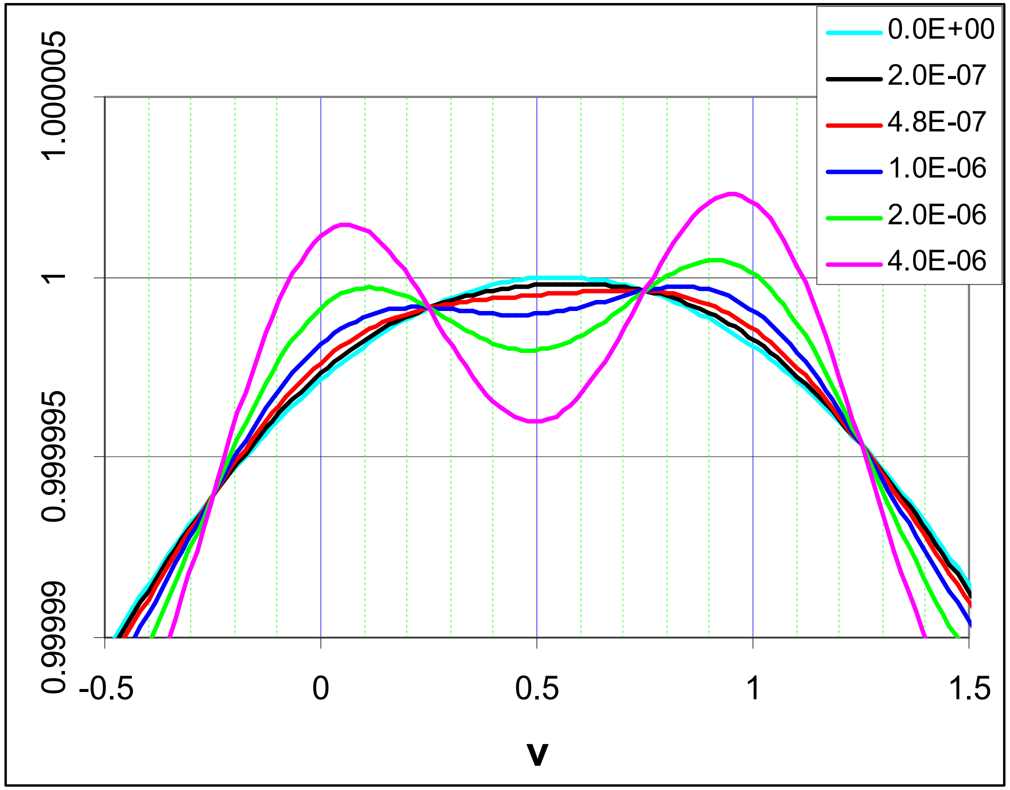
Red curve – final optical feedback of DL DFB and fiber influence. DL will generate at feedback maximum.

Calculation performed are based on real optical feedback measurement ~ 5 10^{-6}. Intention has to be paid to small optical feedback variation critical for DL operation.

Optical feedback

Optical feedback of DFB DL fiber output near DFB optical feedback maximum.

$$\frac{E}{4kNE_0} = \left\{1 - \frac{[8\pi n(\nu - \nu_0)\Lambda N]^2}{6}\right\} + \beta \cos[4\pi \nu L]$$



DFB DL with fiber output for different β values. Frequency v_0 is close to mean of external resonator modes. Let us introduce critical value of external optical feedback β_0 (red curve). It corresponds to zero value of quadratic term in above equation.

$$\beta_0 = \frac{1}{3}\left[\frac{2n\Lambda N}{L}\right]^2$$

<u>For $\beta < \beta_0$ DL will generate near DFB feedback maximum, for $\beta > \beta_0$ generation near external resonator mode will take place.</u>

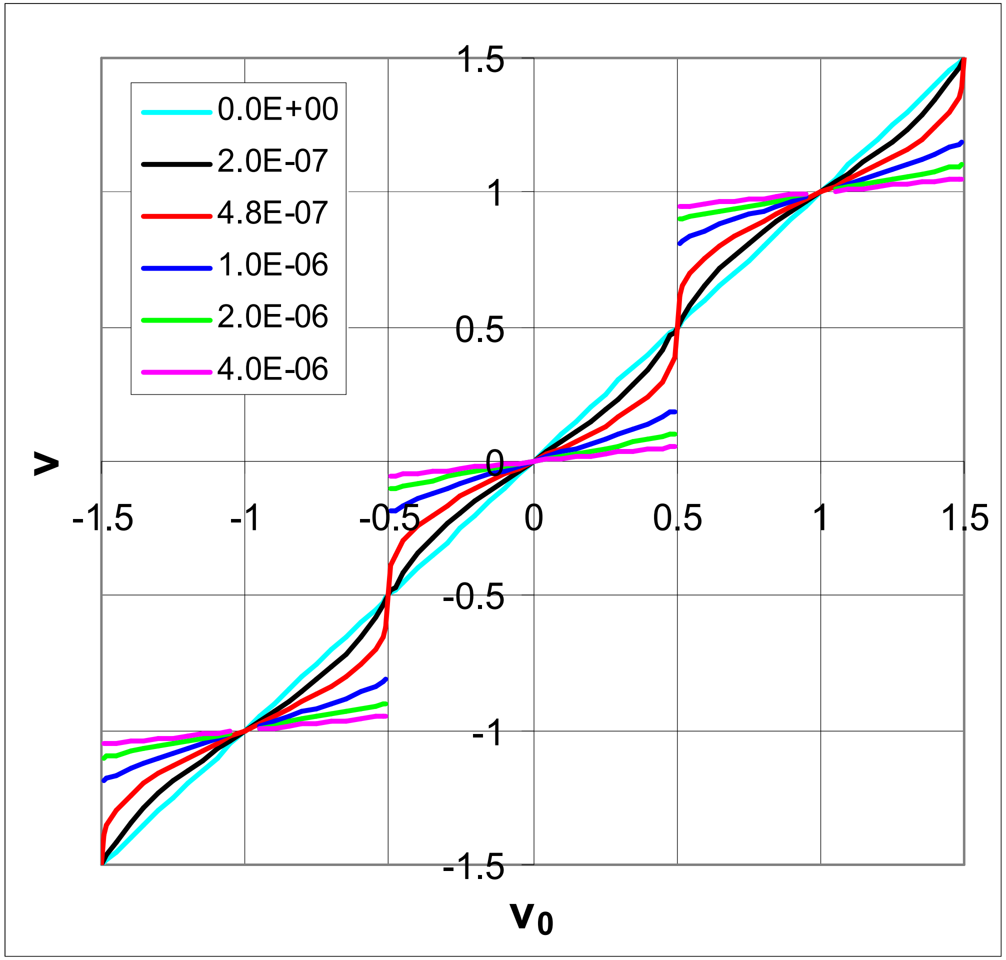
DL frequency tuning

DFB DL with fiber output frequency tuning.

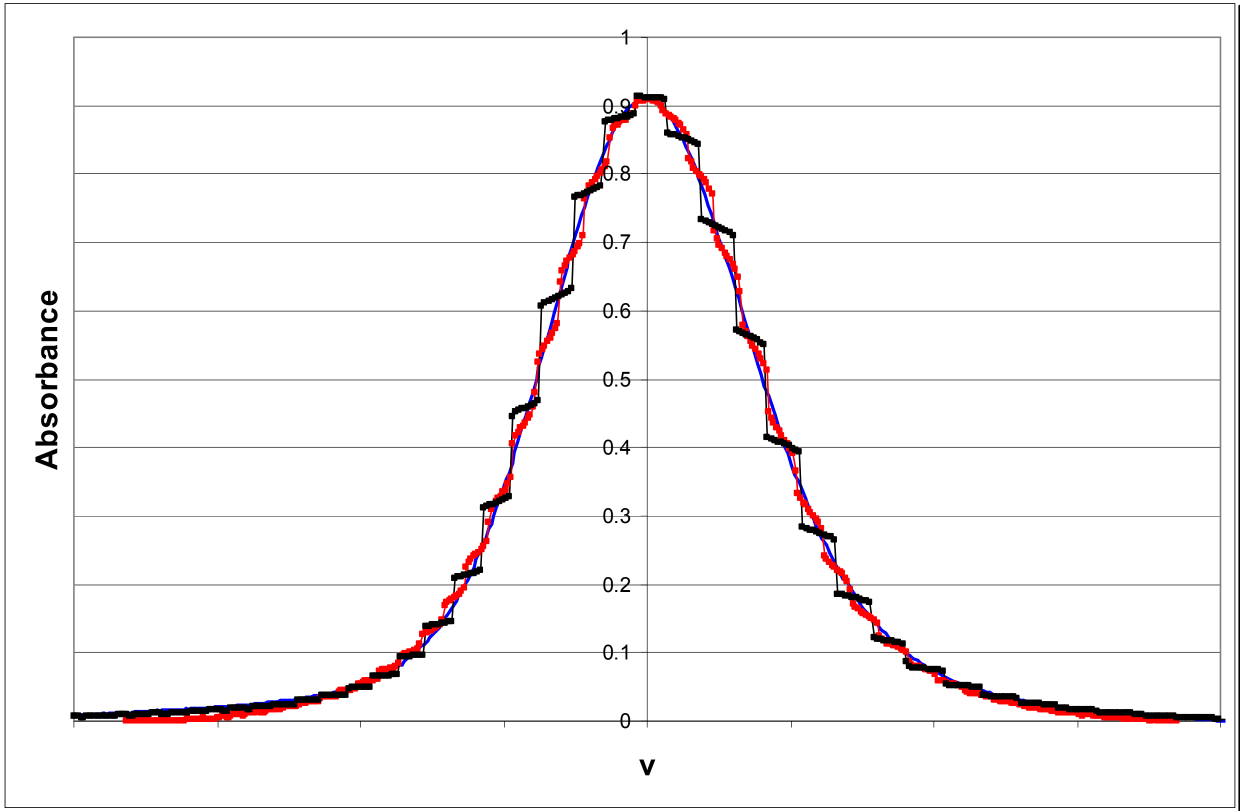
$$\frac{\left[8\pi n \Lambda N\right]^2}{3}(\nu-\nu_0)-4\pi L\beta\sin\left[4\pi\nu L\right]=0$$

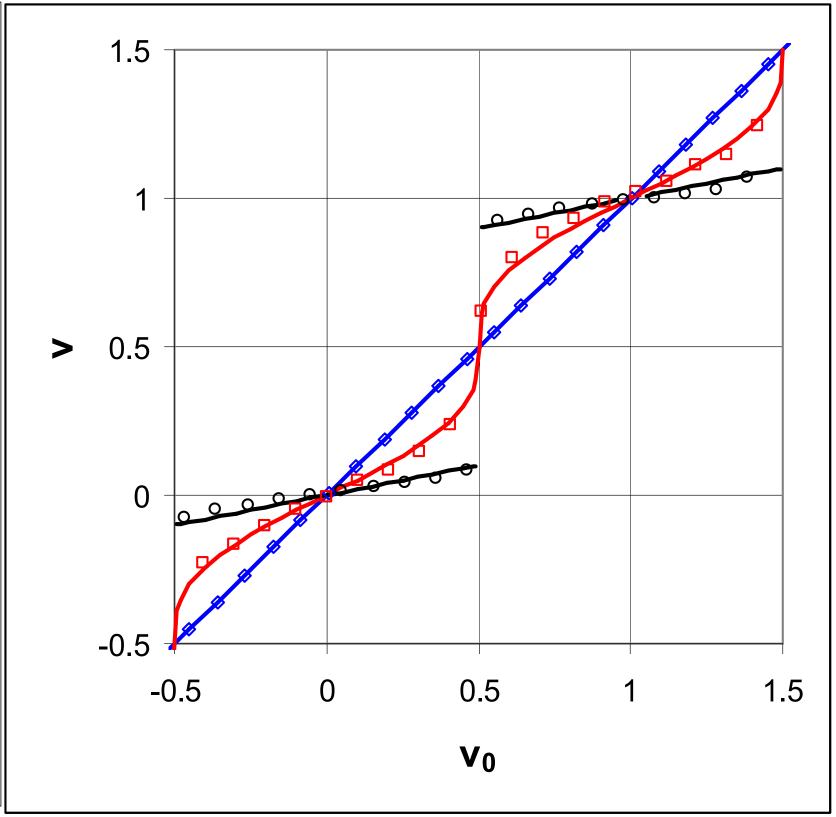
$$\left.\frac{\partial \nu}{\partial \nu_0}\right|_{\nu_0=0}=\frac{\beta_0}{\beta+\beta_0}$$

DFB DL frequency tuning as function of DFB tuning for different β values – DL radiation part reflected back to DL active area. No feedback DL frequency is following DFB. Critical feedback β_0 = 4.8 10^{-7} in present case (red). $\beta > \beta_0$ mode jumps can be observed. DL tuning vs. DFB tuning between two jumps can be used to determine β.



Optical feedback for different DL

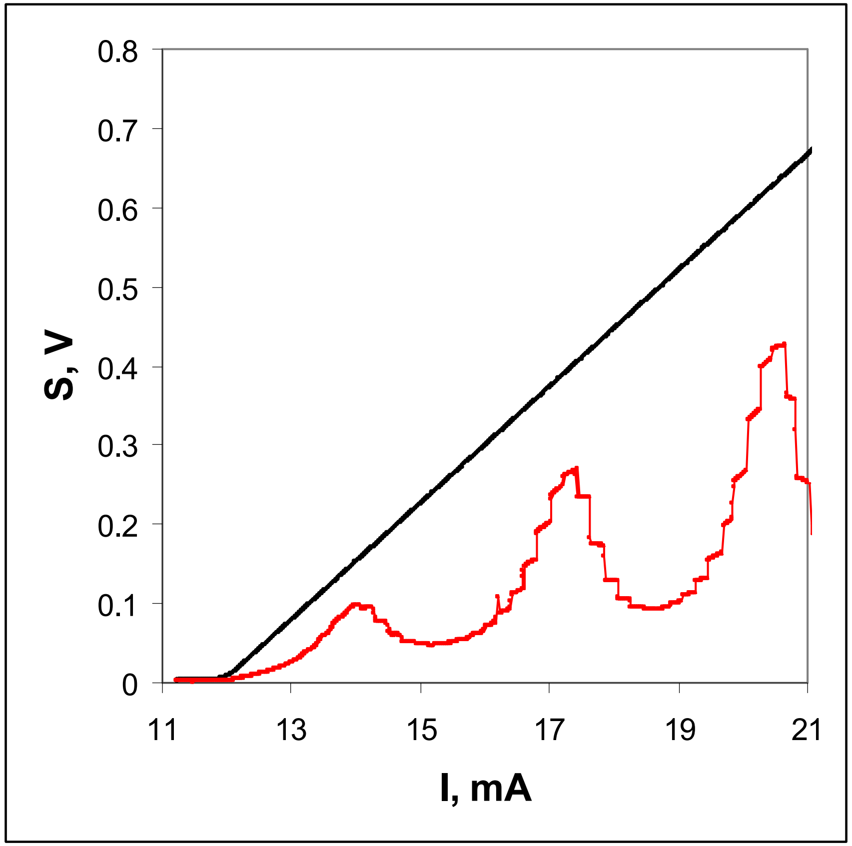


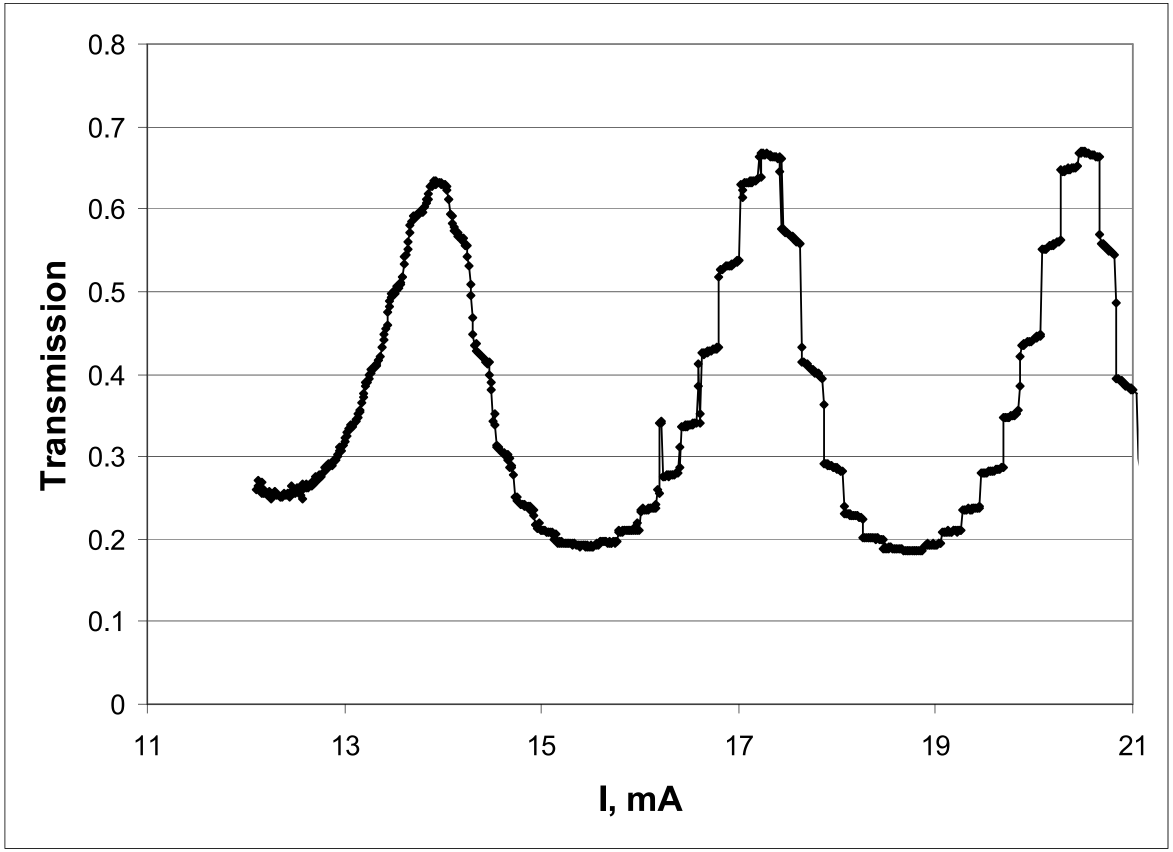


H_2O line recording using three DLs (left). Frequency tuning of these DLs (right).

Blue – Laser Components chip (no external optical feedback), Red – Anritsu (feedback is close to critical one), Black – NEL (frequency jumps can be observed)

DL coherence length

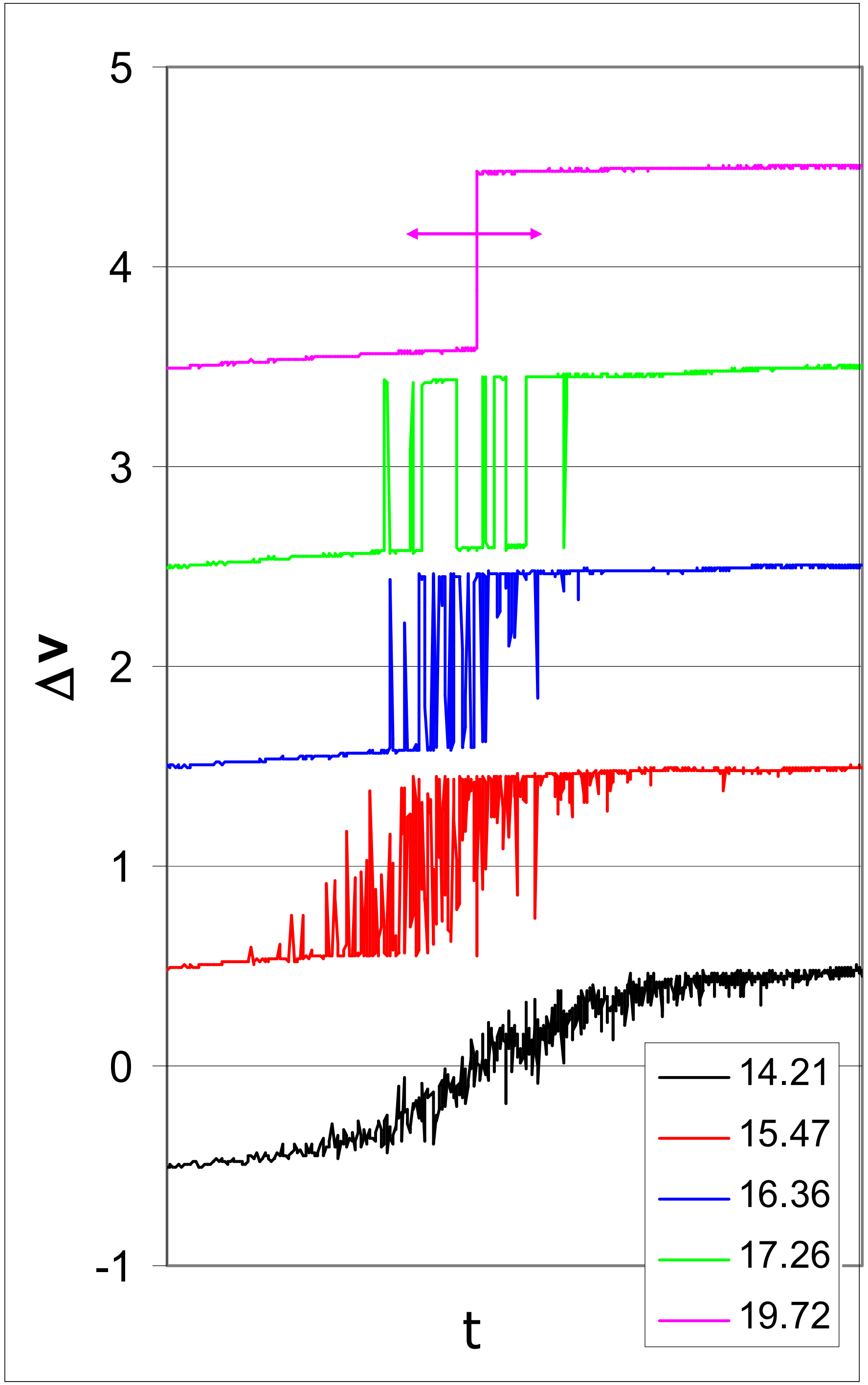




Signal (left) and transmission (right) when FP etalon was installed in NEL DL beam. Significant variation of optical feedback formation efficiency can be observed.

DL coherence length is proportional to DL power and changes significantly near threshold. If coherence length is smaller than external cavity length (fiber length) no optical feedback.

Mode jumps



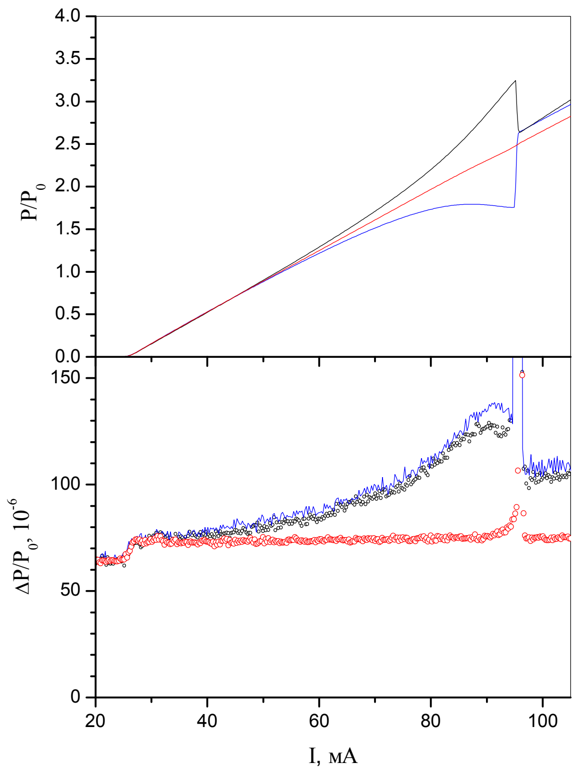
Forms of mode jump for different excitation currents (different DL coherence lengths).

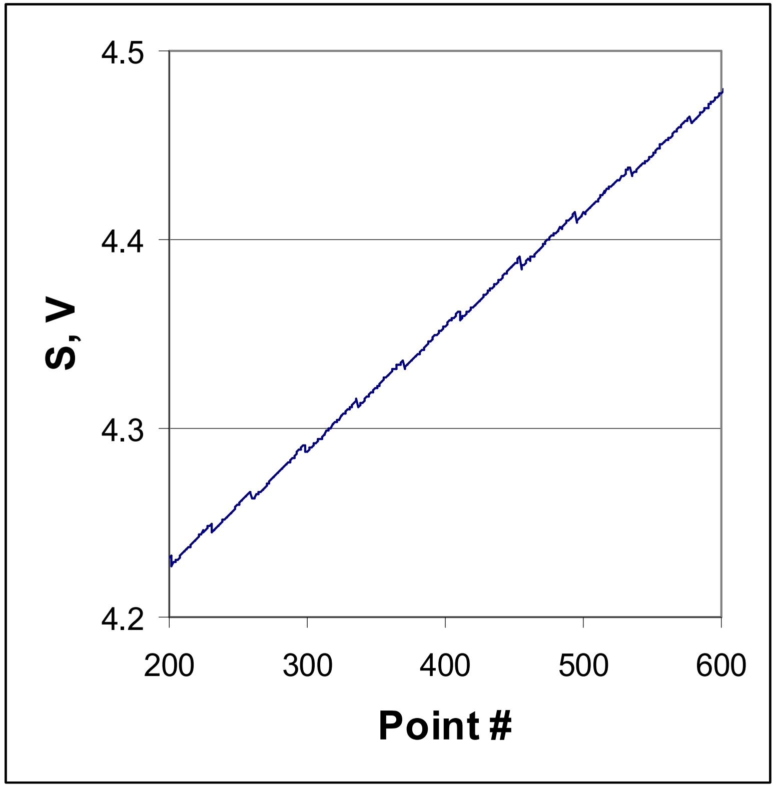
When two neighboring external cavity modes have close feedback bi-stable situation will take place. Due to frequency noise DL will jump between these two modes. Higher frequency noise quicker jumps will take place.

To reduce optical feedback under consideration external cavity length higher than DL coherence length has to be used.

B6 formation

Optical feedback results in frequency jumps. Why it forms baseline? Origin is due to DL near field and diagram changes when mode jump takes place.



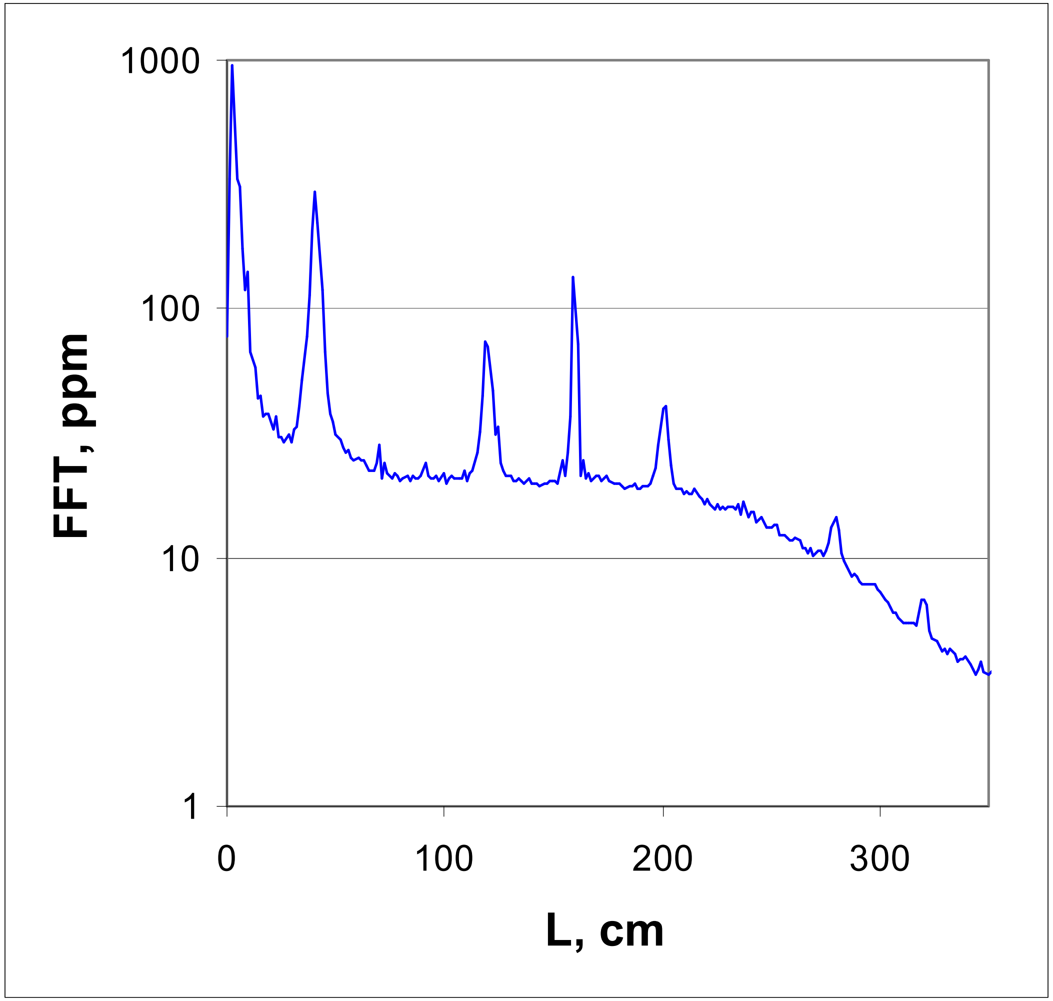


Signal and noise dependences vs. excitation current near mode jump for different PD installation in DL diagram for one DL under investigation.

In case of DL with fiber output we are using manufacture alignment. Non ideal alignment results in Baseline B6.

B6 FFT

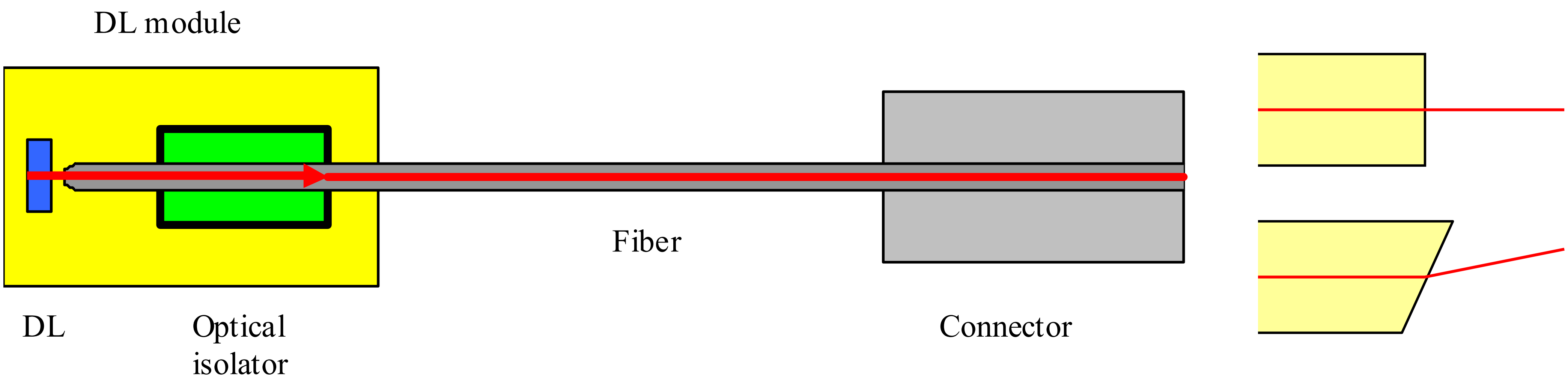
The worst B6 property is its non-linearity (mode jumps). In case of other interference presence all combination frequencies and harmonics will be observed.



In present case optical feedback is determined by fiber length (L=160 cm). At 2 m distance white paper was installed to scatter DL radiation. All combination distances can be observed having amplitude even higher than initial ones.

Conclusion: for trace molecules absorption detection B6 has to be suppressed totally.

DL with fiber output (pigtail) module

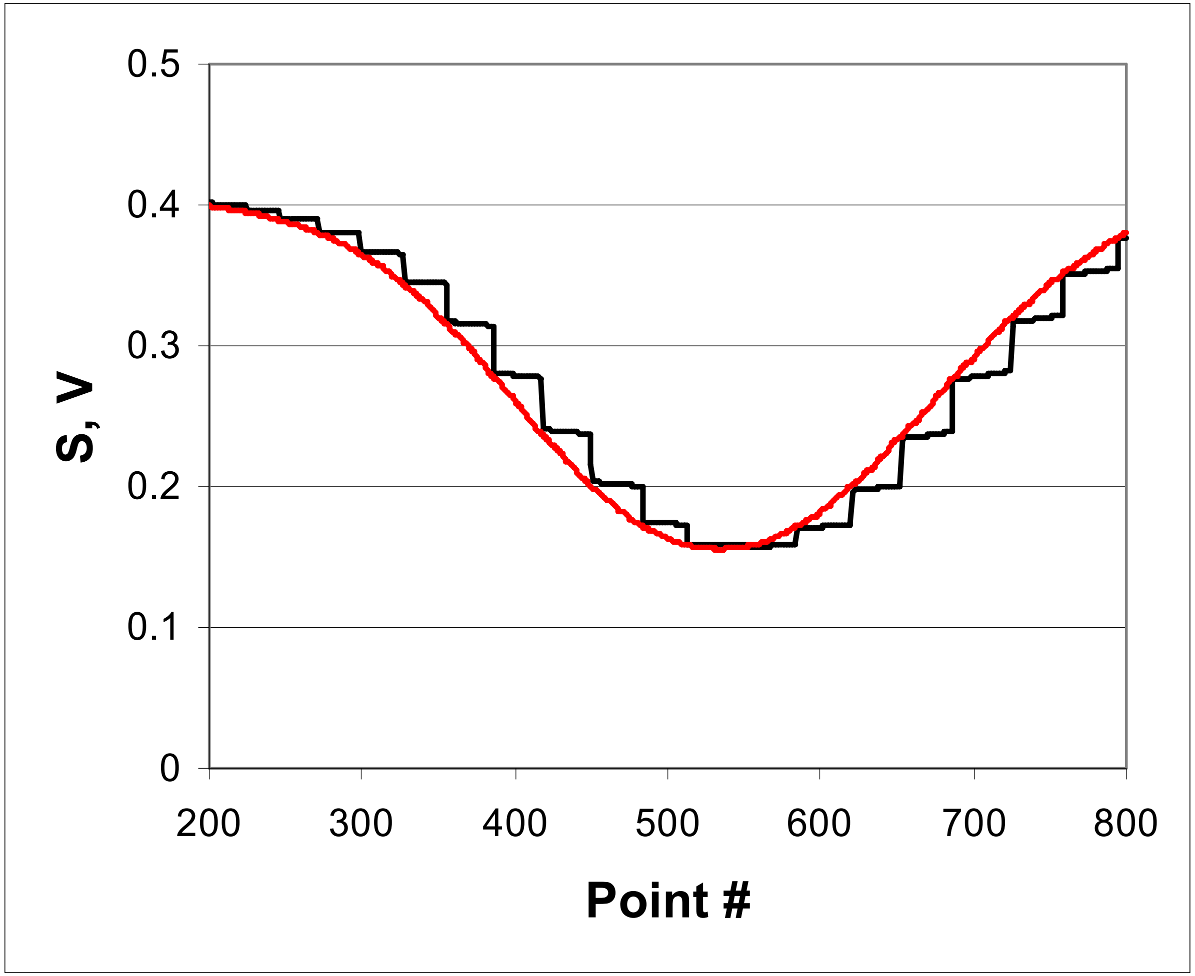


Structure of recent pigtail DL module. Module contains DL, fiber micro lens, optical isolator, fiber, and connector (FC). Fiber micro lens provides efficient connection DL to fiber. Optical isolator (30 – 60 dB) suppresses radiation reflected by connector.

Two types of fiber connectors in use are shown. In picture flat connector facet is shown. For resent connectors it is not flat. These two connectors have following identification: FC/PC and FC/APC - Fiber Connectors with Physical Contact and Angled Physical Contact, respectively.

To reduce optical feedback higher optical isolation and FC/APC have to be used.

B6 suppression



Water line registration using the same DL module.

In present experiment NEL DL (30 dB, FC/PC) was used. Mode jumps due to optical feedback can be observed (black curve).

Based on investigation presented above DL fiber was connected to 3 m cable having FC/PC and FC/APC connectors. Recording of the same water line in this case is shown by red curve. Optical feedback is totally suppressed.

In present case of optical feedback suppression critical is connection of FC/PC DL and cable connectors. Its quality can be controlled by recorded line shape.

Conclusion

Frequency tuning of DL with additional feedback was modeled and analyzed.

There is critical feedback value β_0. If additional feedback $\beta<\beta_0$ DL generates near max of DFB. In opposite case generation takes place near modes of external resonator. It results in mode jumps.

4 DL modules having different additional feedback values were investigated. Results obtained were compared with modeling performed.

DL line width influence on frequency tuning in presence of additional feedback was investigated.

Baseline B6 due to presence of additional feedback was detected and investigated.

Suppression strategy of undesirable effect under consideration was developed and demonstrated.