1/f Noise and Reliability Representation of High Power Semiconductor Laser Diodes Based on Wavelet Transform

Duanyuan Bai [1], Xin Gao [2], Baoxue Bo [1], Liuyang Xu [1], Wenchao He [2], Chen Wang [2], Yubing Liu [2]

[1] Changchun University of Science and Technology, Changchun 130022, China

[2] Jinling University, Changchun 130023, China

Abstract

In this thesis a test bench was designed ,can both test real electronic noise of the laser diodes and analysis with software. And we also carry on some destructive testing, via wavelet transform, the result conform the feasibility of the method using low frenquency electronic noise to represent the reliability of high power semiconductor laser diodes.

Keywords

High power semiconductor laser diodes ; Wavelet transform; 1/f noise; Fractal signal.

1. Introduction

The main component of low frequency noise in high power semiconductor laser diodes is *1/f* fractal noise. *1/f* noise is a kind of unstable stochastic signal, the time-frequency features reflect innate characters of the signal.The traditional analysis method is Fourier Transfom, but it has some limit: after transform we can only get the frequency domain information as a whole of the signal,there is none of information about the local time-frequency features.Wavelet transform can remedy this shortcoming, wavelet transform is a time-frequency (scale) analysis, it can reflect the local features of the signal.Wavelet is a useful analysis tool for *1/f* fractal signal analysising.

2. Denoising and Reconstruction Based on Wavelet Transform

2.1 The Definition of Wavelet

To a basic function $\psi(t)$, let:

$$\psi_{a,b}(t)=\frac{1}{\sqrt{a}}\psi(\frac{t-b}{a}) \tag{1}$$

Where, a,b is constant data, $a>0$. $\psi_{a,b}(t)$ is the result of basic $\psi(t)$ after translation and expansion .When a,b variance continuously, getting a serial $\psi_{a,b}(t)$ .Then,the wavelet transform of $x(t)$ defined as(2):

$$\begin{aligned} WT_x(a,b) &= \frac{1}{\sqrt{a}}\int x(t)\psi^*(\frac{t-b}{a})dt \\ &= \int x(t)\psi^*_{a,b}(t)dt = \langle x(t),\psi_{a,b}(t)\rangle \end{aligned} \tag{2}$$

$$\text{Where, }\psi_{a,b}(t)=\frac{1}{\sqrt{a}}\psi\left(\frac{t-b}{a}\right)$$

2.2 The Reconstruction based on Wavelet Transform

The wavelet reconstruction kernel function can be expressed as:

$$WT_x(a_0,b_0)=\int_0^{\infty}a^{-2}\int_{-\infty}^{\infty}WT_x(a,b)K_{\psi}(a_0,b_0;a,b)dadb \tag{3}$$

Where $WT_x(a_0,b_0)$ value of $WT_x(a,b)$ at (a_0,b_0) and is the wavelet reconstruction kernel.

2.3 Denoising and Reconstruction of *1/f* based on Wavelet Analysis

Low frequency voltage noise can reflect the defects of oxide layer and crystal lattice dislocations in high power semiconductor laser diodes,so could as the characterization of device reliability and quality.Usually,should denoising white noise firstly,using fractal theory based wavelet transform coefficient method.Under the same scal a, the discrete wavelet transform coefficient d_a^b of *1/f* fractal signal with the frequncy index γ is similar stable stochastic signal.

The corresponding power spectrum is :

$\frac{\sigma_X^2}{|\omega|^{\gamma}}$; and $\int_{-}^{+} t^k\psi(t)dt=0, 0\le k<N$,

$$d_a^b=\langle x(t),\psi(t)_{a,b}\rangle=\int x(t)\cdot 2^{-\frac{a}{2}}\psi(2^{-a}t-b)dt \tag{4}$$

Where, N is wavelet Vanishing Moments, $\psi(t)$ is mother wavelet, a is thescalefactor, b the shift factor, and the autocorrelative function of the wavelet transform coefficient is as formula (5) :

$$\begin{aligned}E[d_b^a d_{b'}^{a'}]&=\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}E[x(t)\psi_{a,b}(t)x(t')\psi_{a,b}(t')]dtdt'\\&=\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}\psi_{a,b}(t)R_x(t-\tau')\psi_{a',b'}(t')dtdt'\\&=\int_{-\infty}^{+\infty}\psi_{a,b}(t)[R_X(t)*\psi_{a',b'}(t)]dt\end{aligned} \tag{5}$$

According parseval theorem:

$$E[d_b^a d_{b'}^{a'}]=\frac{2^{\frac{a+a'}{2}}}{2\pi}\int_{-\infty}^{+\infty}\frac{\sigma_x^2}{|\omega|^{\gamma}}\psi(2^a\omega)\psi^*(2^{a'}\omega)e^{-j(b2^a-b'2^{a'})}d\omega \tag{6}$$

Let $\Omega=2^m\omega$, then:

$$\begin{aligned}E[d_b^a d_b^a]&=\frac{2^a}{2\pi}\int_{-\infty}^{+\infty}\frac{\sigma_X^2}{|2^{-a}\Omega|^{\gamma}}\psi(\Omega)\psi^*(\Omega)2^{-a}d\Omega\\&=\frac{2^{a\gamma}}{2\pi}\int_{-\infty}^{+\infty}\frac{\sigma_X^2}{|\Omega|^{\gamma}}|\psi(\Omega)|^2d\Omega\end{aligned}$$

$$= 2^{\gamma a}\sigma^2 \qquad (7)$$

Where, $\sigma^2 = \frac{1}{2\pi}\int_{-\infty}^{+\infty}\frac{\sigma_X^2}{|\Omega|^\gamma}|\psi(\Omega)|^2 d\Omega$ .And the coefficient of wavelet transform d_a^b is stable stochastic process of variance σ_w^2 .Apply this theory to the noise data obtained through data card 1 in #14 device. After denoising and reconstruction the noise data via wavelet transform, the result are as fig1 to fig2.

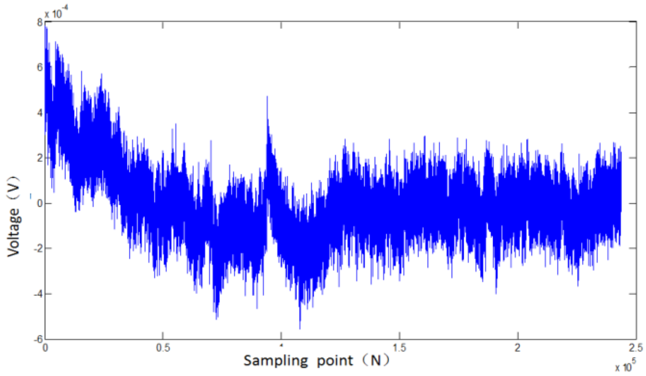

Fig1 The Original *1/f* Noise Data

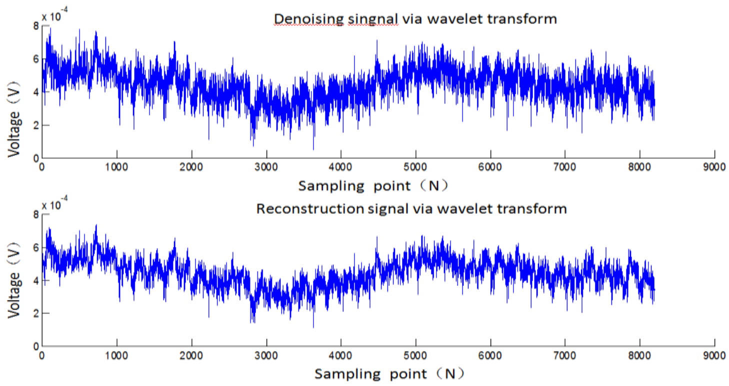

Fig2. Denoising and Reconstruction *1/f* Noise via Wavelet Transform

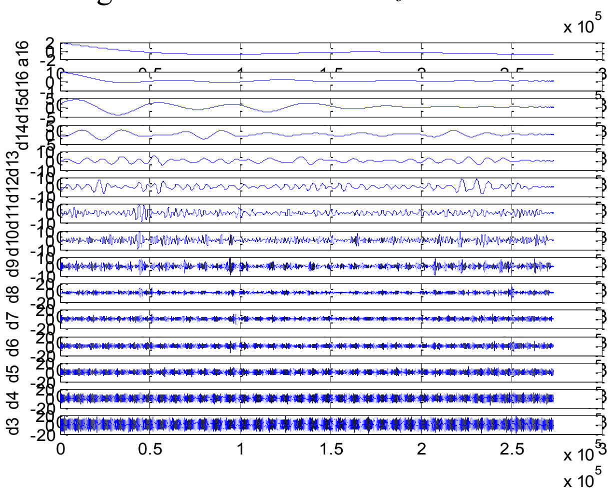

Fig3. 16 Layers Wavelet Decompositon of *1/f* Noise beforeDevice Destroyed

3. Reliability Representation Based on Wavelet Transform

The low frequency noise method has sensitivity, universality, avoiding destroying features, will become as an impotant approach to appraise the reliability of semiconductor laser diodes. In this part we destroyed semiconductor device, the comparison of power spectrum desity melely can hardly draw a conclusion which has higher reliability. Then we apply wavelet decomposition to the noise data. The 16 layer wavelet decomposition of the device *1/f* noises, before and after destroyed are shown in fig3.and fig4.

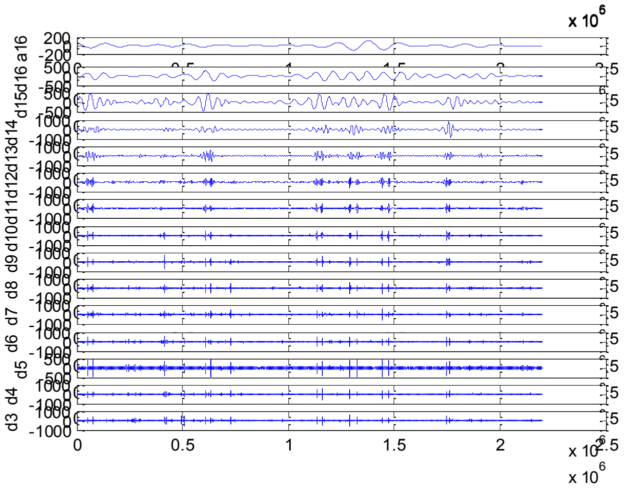

Fig4. 16 Layers Wavelet Decompositon of *1/f* Noise after Device Destroyed

Compare fig3, fig4, the coefficient of higher layer of wavelet decomposition fluctuate more severely. According to this phenomenon we can single out the lower reliability high semiconductor laser diodes.

4. Conclusions

This thesis research the *1/f* noise via wavelet transform, discuss the relationship between fluctuation degree of *1/f* noise wavelet decomposition coefficient and device reliability. The experiment results reveal that wavelet analysis is suitable for 1/f stochastic signal analysising, and can be a undamaged method for high power semiconductor laser diodes reliability detection.

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