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Research of the Different Light Source upon the Output of Optical Current Transformer

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Abstract

The research of different light source on pulse broadening causing by fiber dispersion has been theoretically investigated and simulated of optical current transformer. There is no light source spectral width to consider the impact of the results till now. The studies show that the outputs of optical current transformer are different when the different spectra width of different light sources, and our experimental results verify above conclusions. That show that the effect is small enough and the treatment of using monochromatic model to describe broad-band systems is reasonable and feasible, if the wavelength accumulation effects of the other optical parameter of sensing head are not considered. The results can provide a reference for optical current transformer practical research.

Keywords: *Optical current transformer; Broadband Optical Source, Fiber Dispersion, Pulse Broadening*

1. Introduction

Optical current transformers (OCTs) are the kind of devices that directly or indirectly realize the transformation or measurement of current in order to achieve the sensing of the current, it based on modern electronic technology and optics technology has many excellent characters. The substitution of OCT for the current-transforming techniques based on electromagnetic induction is a revolutionary evolution in the techniques of current measurement and power line protection in the industry of power delivery, it has already been accepted by electric power engineering with the development of electric power industry [1-3].

This paper focuses on the effect of spectral width of the optical source on the output of active optical current transformer (AOCT). For AOCT, the effect of broadband light sources on pulse broadening causing by fiber dispersion has been theoretically investigated and simulated, finally, our experimental results verify above conclusions. The work is significant in both theory and engineering applications.

2. Theoretically Investigated

2.1. Connection of Pulse Broadening and the Output of AOCT

The composed of the AOCT systems are include the part of high-pressure, the optical transmission and the low side. Where high and low pressure side of the fiber is to

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contact the media, did not participate in the process of the current sensing [4-6]. However, optical fiber as the information channels of transmission, the impact of the signal light output can cause the system to change, so the change should be discussed in optical fiber transmission due to the signal.

The optical signal will produce distortion in optical fiber transmission process, and more and more serious with the propagation distance increases. This distortion is become of the propagation delay between the model itself and model the dispersion difference. The dispersion model itself, which is called mode dispersion, it refers to a single mode pulse broadening occurred. For the AOCT systems, signal distortion form fiber dispersion impact on the system output, resulting in this distortion because of the light source emitted light has a certain spectral width, and the group rate is a function of wavelength. Dispersion and the wavelength of mold-related, so signal distortion is greater for the wider spectrum of optical source.

The alternating current of signal be transmission for AOCT, analog signals should be used to represent. In analog transmission, dispersion is not the same for different frequencies of the analog optical signal spectrum, so the receiver will make a serious distortion of analog signals. From the point of view the time domain analysis, that fiber dispersion can cause pulse waveform broadening, and the frequency domain from the point of view, optical fiber dispersion says there is a certain fiber transmission bandwidth. Therefore, pulse width and bandwidth is different angle optical transmission characteristics of two closely linked parameters. So, in theory, the dispersion can cause pulse broadening to replace the source spectral width of the output of the AOCT system.

2.2. Derivation of Broadband Light Source on Pulse Broadening

Material dispersion is the main sources of the pulse broadening by the source spectral width, in the AOCT system of multi-mode optical fiber transmission. Material dispersion origin of the refractive index is a function of wavelength, and the group velocity Vg is the mode function of refractive index, so transmission rates of different components of the spectrum is a function of wavelength [7, 8].

Suppose the modulated optical signals equally excite all the modes in fiber inputs, each carrying the same optical power, and within each mode contains all of the spectral light weight. When the optical signal propagation in the fiber, it can be seen as independent of each spread spectrum, then the unit in the direction of propagation delay experienced by distance, which was expressed as:

$$\frac{\tau_g}{L} = \frac{1}{V} = \frac{1}{c}\frac{d\beta}{dk} = -\frac{\lambda^2}{2\pi}\frac{d\beta}{d\lambda} \tag{1}$$

To calculate the dispersion for the material, we assume an infinite plane wave in the electrolyte in the spread, and the refractive index n is same as the core of the fiber, then the propagation constant β as:

$$\beta = \frac{2\pi n(\lambda)}{\lambda} \tag{2}$$

Eq. (2) into (1), and to k = 2π/ λ, and group delay τmat for material dispersion as:

$$\tau_{mat} = \frac{L}{c}\left(n - \lambda\frac{dn}{d\lambda}\right) \tag{3}$$

If the source spectral width $\delta\lambda$ is expressed as the rms value, the degree of pulse broadening can be approximated by the rms pulse width:

$$\sigma_g \approx \left|\frac{d\tau_g}{d\lambda}\right|\sigma_\lambda = \frac{L\sigma_\lambda}{2\pi c}\left|2\lambda\frac{d\beta}{d\lambda} + \lambda^2\frac{d^2\beta}{d\lambda^2}\right| \quad (4)$$

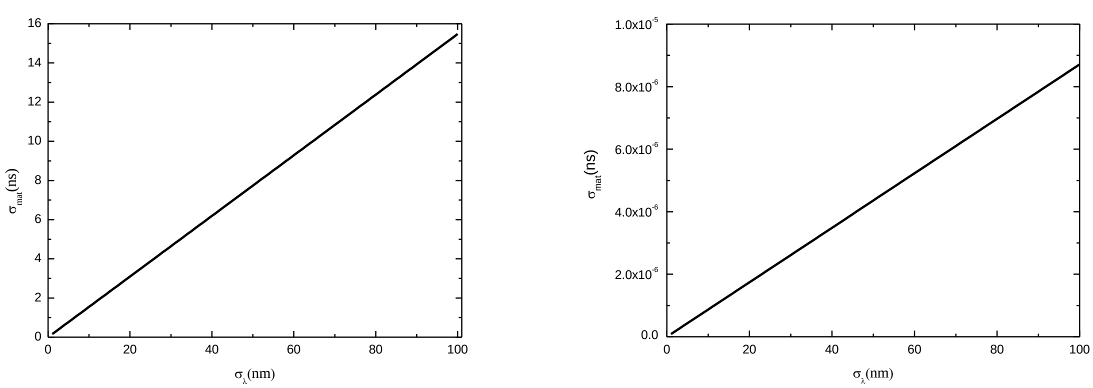
Application of Eq. (4), when the light spectrum is σ_λ, the pulse broadening σ_{mat} as in (5):

$$\sigma_{mat} = \left|\frac{d\tau_{mat}}{d\lambda}\right|\sigma_\lambda = \frac{\sigma_\lambda L}{c}\left|\lambda\frac{d^2 n}{d\lambda^2}\right| \quad (5)$$

Eq. (5) is the relationship of pulse broadening and the output of AOCT of multi-mode optical fiber transmission.

3. Theoretically Simulated

For multi-mode optical fiber transmission system under the AOCT, by Eq. (5) and the Sellmeier dispersion formula for refractive index of the ZF-7 glass [9], and the experimental system with the length of fiber L = 500m, center wavelength of light = 620nm, using Mathematica software simulation available pulse width changes with the source spectral width in Figure 1 (a). Can be seen from the Figure 1 (a): optical source spectral width in the 0-100nm range of changes, the corresponding change in pulse width is small, the level of 10ns; with the source spectral width increases, the output signal of the pulse width increases; when the spectra width of light sources varies between 15-25 nm, the pulse broadening of multimode fiber with length of 500 m is 1-3.5 ns, the effect is less enough on the system.



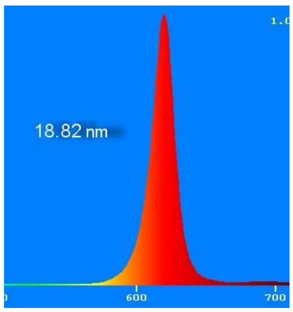
a. Multi-mode Fiber Transmission **b. Single-mode optical fiber Transmission**

Figure 1. Pulse Width Changes with the Source Spectral Width

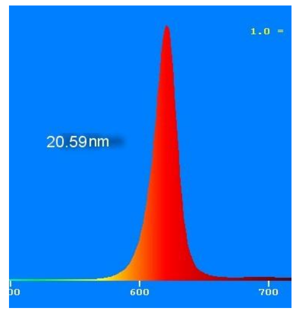
For single-mode optical fiber transmission system under the AOCT, the use of correlative concluded [10], the corresponding 500m long optical pulse broadening corresponding to the Figure 1 (b). Can be seen from the Figure 1 (b): the source spectral width in the rms value of changes in the range 0-100nm, the corresponding change in pulse width of the lever of 10-6 ns; with the source spectral width increases, the output signal of the pulse width increases; in the source spectral width of 15-25nm range, the pulse broadening in the 1×10^{-6}-2×10^{-6}ns range of changes, less impact on the system.

4. Experimental

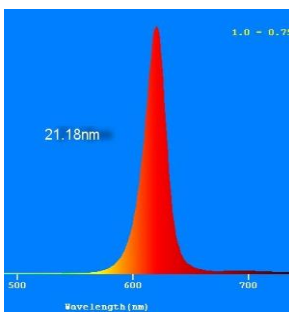
The single-mode optical fiber transmission system under the AOCT broadband light source effects on the difference between the 10^{-5} relative to the multi-mode optical fiber, from the conclusions of the previous simulation, so system output that can be ignored. We verify in the experiment only under a multi-mode fiber of AOCT system.



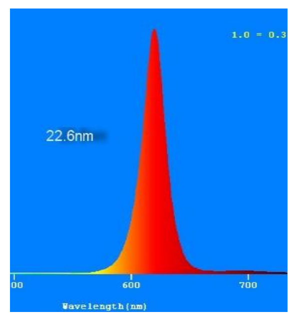
a. Spectral width is 18.82 nm of LED-1



b. Spectral width is 20.59 nm of LED-2



c. Spectral width is 21.18 nm of LED-3



d. Spectral width is 26.60 nm of LED-4

Figure 2. (Colour online) Spectrogram of the Optical Source

We have measured the spectral width of light sources of different system output voltage with variation of current in the experiment, under test to verify the above simulation of light in different spectral width of the output signal of the AOCT system the impact of pulse width. Spectral width were selected in four different Light-emitting diode (LED), the grating spectrometer to measure the spectrum LED before the experiment. The spectra are shown in Figure 2. The figure shows, the spectral width were 18.82nm, 20.59nm, 21.18nm and 22.60nm, respectively.

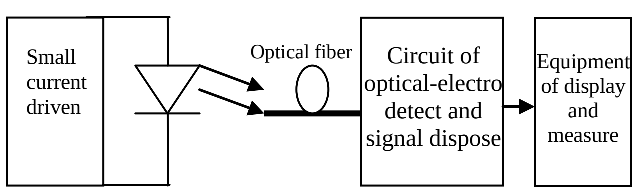
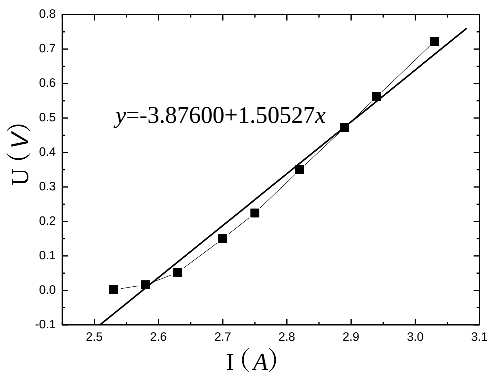
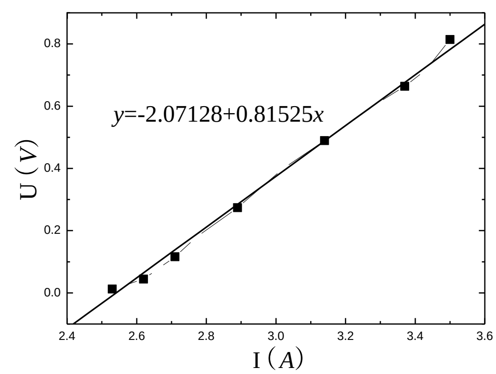


Figure 3. Sketch Map of Experimental Installation of ACOS

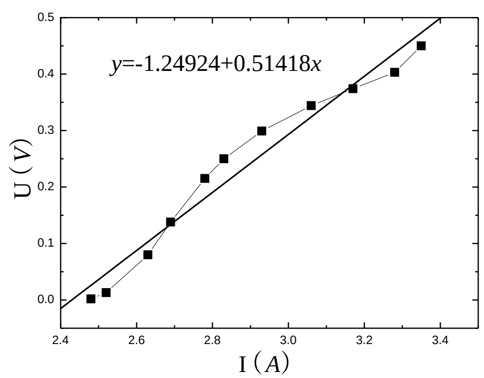
Devices used in the experiment shown in Figure 3. Large current signal under test by using conventional CT is transformed into a small current-driven, light source to achieve electro-optical signal conversion. The output optical signal light transmitted through optical fiber to the area of low pressure achieved by the photoelectric detector photoelectric conversion, transfer to amplify the signal processing circuit, filtering and display. The size of the current signal changes in experiments, then low-pressure side with a voltage meter test data and records.



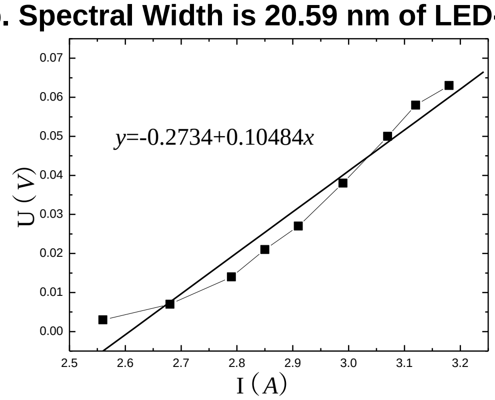
a. Spectral Width is 18.82 nm of LED-1



b. Spectral Width is 20.59 nm of LED-2



c. Spectral Width is 21.18 nm of LED-3



d. Spectral Width is 26.60 nm of LED-4

Figure 4. Experimental Curves

Experimental data be shown in Table 1, the corresponding experimental curve be shown in Figure 4. From Figure 4: Output voltage is linear with the change of the current under test, the slope of the line 1.50527, 0.51418, 0.81525 and 0.10484, with the spectral width were 18.82nm, 20.59nm, 21.18nm and 22.60nm, respectively. In the AOCT, the system output signal is larger with the bigger spectral width of the LED. And then, experimental verification of the above qualitative conclusion, *i.e.*, as the light source line width increases, the system output decreases.

Table 1. Experimental Data

	LED-1		LED-2		LED-3		LED-4	
No.	Signal current (A)	Measured output (V)	Signal current (A)	Measured output (V)	Signal current (A)	Measured output (V)	Signal current (A)	easured output (V)
1	3.03	0.722	3.35	0.45	3.5	0.814	3.18	0.063

2	2.94	0.562	3.28	0.403	3.43	0.716	3.12	0.058
3	2.89	0.472	3.17	0.374	3.37	0.664	3.07	0.05
4	2.82	0.35	3.06	0.344	3.29	0.609	2.99	0.038
5	2.75	0.224	2.93	0.299	3.14	0.489	2.91	0.027
6	2.7	0.15	2.83	0.25	3.02	0.399	2.85	0.021
7	2.63	0.052	2.78	0.215	2.89	0.274	2.79	0.014
8	2.58	0.016	2.69	0.138	2.77	0.178	2.68	0.007
9	2.53	0.002	2.63	0.08	2.71	0.116	2.56	0.003
10	–	–	2.52	0.013	2.66	0.076	–	–
11	–	–	2.48	0.002	2.62	0.044	–	–
12	–	–	–	–	2.56	0.023	–	–
13	–	–	–	–	2.53	0.012	–	–
14	–	–	–	–	2.5	0.005	–	–

5. Conclusions

In this study, we discussed in the broadband light source in the AOCT impact on the system output by theoretical analysis, simulation and experimental studies. Theoretical and experimental results show that, AOCT in the source spectral width has little effect on the system output that can be ignored. Therefore, the treatment of using monochromatic model to describe broadband systems is reasonable and feasible, if the other optical parameters' dispersion of the sensing head are not considered. The results provide a possible reference for further research in the optical current sensing techniques area.

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