Quantum Electronics 30 (4) 323 – 324 (2000)

CONTROL OF LASER RADIATION PARAMETERS

PACS numbers: 42.60.Fc; 42.65.Hw
DOI: 10.1070/QE2000v030n04ABEH001717

Experimental study of a passive gate based on nonlinear internal reflection

I M Korda, A N Rubinov

Abstract. The separation of a radiation pulse from an Nd laser into three sequential pulses is experimentally studied by using a passive gate based on nonlinear internal reflection. The possibility of controlling the duration of each of the gated pulses is demonstrated. It is shown that this passive gate allows one to decrease the duration of the laser pulse by an order of magnitude.

Nonlinear internal reflection (NIR) at the interface between a transparent dielectric and an absorbing medium and its application for Q-switching of solid-state lasers have been demonstrated in Refs [1, 2]. These studies were further developed in Refs [3, 4] where the methods for shortening laser pulses by using NIR in conjunction with the interference in a thin layer were proposed and implemented. In Ref. [5] a device based on a passive NIR gate was proposed, which allows one to separate a shorter pulse with a variable duration from a laser pulse. In this paper, such a device is implemented and tested.

A schematic diagram of a passive NIR gate is presented in Fig. 1. The device includes two glass prisms, with a thin layer of a highly absorbing liquid placed between their hypotenuse faces, and a totally reflecting mirror. A laser pulse is incident on the glass – liquid interface at an angle α_1 that is slightly smaller than the critical angle of total internal reflection α_{cr} (Fig. 1). The refractive indices of both media are chosen in such a way that the very first reflection at the interface is small and the main portion of the emission passes through the double layer. Since the thickness of the liquid layer is chosen to be small, the transmission of the layer is large even for large absorption coefficients of the liquid. Nevertheless a portion of the emission energy is absorbed in the layer, resulting in its heating and, consequently, in a reduction in the refractive index of the liquid. As a result, the critical angle of total internal reflection α_{cr} decreases gradually and becomes smaller than the angle of incidence α_1 at a certain time.

In this case, the pulse is divided into two parts: an initially transmitted pulse I_{1t}, which is a leading edge of the incident pulse, and an initially reflected pulse I_{1r} which is the incident pulse without its leading edge. The reflected emission is returned back to the layer by using mirror (3) in such a way that the repeated angle of incidence α_2 would be smaller than α_1. In this case, the emission I_{2t} first passes through the

I M Korda, A N Rubinov B I Stepanov Physics Institute, National Academy of Sciences of Belarus, 68 Scorina prospect, Minsk, 220072, Belarus

Received 16 December 1999
Kvantovaya Elektronika **30** (4) 323 – 324 (2000)
Translated by Peter P Vasil'ev; edited by L Dwivedi

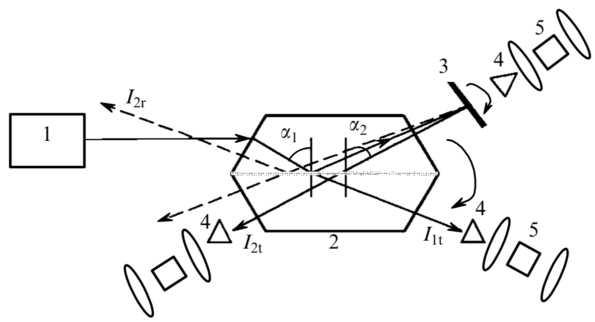

Figure 1. Experimental setup (1) Nd:YAG laser; (2) nonlinear gate; (3) retrodirective mirror; (4) photodetector; (5) calorimeter.

absorbing layer by heating the liquid further. The liquid temperature rises, and the critical angle of total internal reflection α_{cr} decreases. After a certain time, the critical angle becomes smaller than the repeated angle of incidence α_2. The propagating pulse I_{2t} is cut off at this point due to the switching on of the total internal reflection. Thus the passive gate divides the incident pulse into three pulses, namely, I_{1t}, I_{2t}, and I_{2r}. Note that both the leading and trailing edges of pulse I_{2t} are cut and its duration can be varied by a small rotation of mirror (3).

In experiments with a NIR gate, we used prisms made of K8 glass with a refraction index of 1.5063. A 20 μm thick layer of the solution of a 3274 polymethine dye in benzyl alcohol was placed between the prisms. The layer had an absorption coefficient of 14 cm^{-1} and a refractive index of 1.4907. An Nd laser operating in a free-running mode was used as the radiation source. The duration of the laser pulses was about 800 μs and the emission energy was 1.5 – 1.8 J. Special attention was paid to the angular divergence of the incident emission. Since the condition for total internal reflection is fulfilled at different times for different angular components, the increase in the angular divergence of the emission will eliminate modulation of the incident radiation intensity. In our case, the laser beam divergence was 1.6′, which was close to the diffraction limit.

We measured the energy and shape of the following radiation pulses: the pulse incident on the gate (I_0), the initial transmitted pulse (I_{1t}), the second transmitted pulse (I_{2t}), and the second reflected pulse (I_{2r}). The angle of incidence α_1 on the interface at the first reflection was chosen to be 20 – 60′ smaller than α_{cr} for the pair of media under study. The angle α_{cr} was determined experimentally from the angular dependence of reflection of the same laser beam whose intensity was reduced by a few orders of magnitude. Once the leading edge of the incident pulse has passed through the liquid solution, the total internal reflection is realised, and the reflected pulse I_{1r} was directed on a totally reflecting mirror (3).

First, we measured the dependences of the energy and duration of the transmitted pulse I_{1t} on the angular detuning $\Delta\alpha_1 = \alpha_{cr} - \alpha_1$. The detuning was performed by varying the angle of incidence α_1 of the initial pulse on the interface by rotating the nonlinear gate in a controllable way. The results of measurements are presented in Fig. 2. One can see that, when the angle of incidence α_1 approaches the initial value α_{cr}, the duration of the transmitted pulse I_{1t} substantially decreases (by up to a factor of ten with respect to the incident pulse) and its energy derceases.

Second, we measured parameters of the second transmitted (I_{2t}) and second reflected (I_{2r}) pulses as a function of the difference of the angles of incidence $\Delta\alpha_2 = \alpha_1 - \alpha_2$. This difference was varied by changing the second angle of incidence α_2 by rotating mirror (3). The duration of the transmitted pulse I_{2t} changed from 100 to 280 μs when the angular detuning $\Delta\alpha_2$ was varied from 20′ to 180′. This pulse represents the central part of the incident pulse which was cut off by the gate. Because the leading edge of the pulse I_{2t} was formed during the first switching on of the total internal reflection and the trailing edge was formed during the second one, the steepness of these edges is much greater than that of the incident pulse. As a result, the shape of the gated pulse I_{2t} approaches a rectangular form.

Thus the proposed gate allows us not only to decrease substantially (by an order of magnitude) the duration of the laser pulse, but also to divide the incident pulse into three subsequent pulses I_{1t}, I_{2t}, and I_{2r}. Fig. 3 shows the oscilloscope traces of all these pulses and the oscilloscope trace of the initial pulse I_0 for the angular detunings $\Delta\alpha_1 = 10'$ and $\Delta\alpha_2 = 20'$. It is important to note that this gate can operate at any wavelength in the visible spectral range because an ordinary linear (rather than saturable) absorber is used, which can be easily chosen for any spectral range.

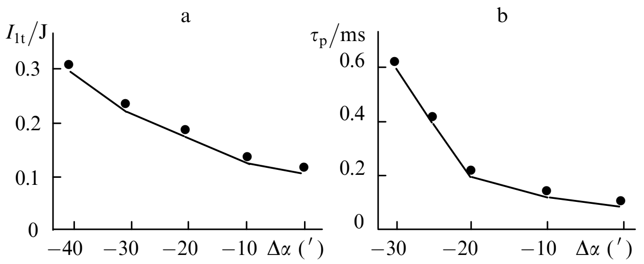

Figure 2. Dependencies of (a) the energy and (b) duration of the transmitted pulse $I_{1t}(t)$ on the angle detuning $\Delta\alpha_1$.

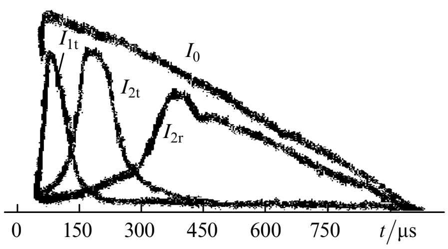

Figure 3. Oscilloscope traces of the initial pulse I_0, the pulses transmitted once (I_{1t}) and twice (I_{2t}), and the second reflected pulse I_{2r}.

Acknowledgements. This work was supported by the International Scientific and Technical Centre (Grant No. B-078).

References

1. Rubinov A N, Korda I M Kvantovaya Electron. (Moscow) No. 4 (16) 96 (1973) [Sov. J. Quantum Electron. **3** No. 4 334 (1973)]
2. Korda I M, Rubinov A N Kvantovaya Electron. (Moscow) **8** 1877 (1974) [Sov. J. Quantum Electron. **4** 1048 (1974)]
3. Dzilavdari I Z, Olefir G I, Petrov N S Zh. Prikl. Spektrosk. **30** 699 (1979)
4. Insarova N I, Olefir G I Zh. Prikl. Spektrosk. **42** 255 (1985)
5. Rubinov A N, Korda I M, Bibik A I Zh. Prikl. Spektrosk. **64** 325 (1997)