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# Use of an iodine active quantum filter for image intensification

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***Abstract*. Intensification of the image brightness using an iodine active quantum filter is studied experimentally. The image brightness was intensified by a factor of 3000 while preserving the diffraction-limited resolution. The obtained results suggest the possibility of using an iodine active quantum filter in laser ranging and laser probing.**

***Keywords***: *photodissociation iodine laser, active quantum filter, quantum sensitivity limit, diffraction-limited resolution quality, video camera, noise signal, laser ranging, laser probing*

## 1. Introduction

An active quantum filter (AQF) based on an iodine photodissociation laser features a very narrow amplification line ($0.01\ \text{cm}^{-1}$) and has an extremely high sensitivity, which is restricted only by the quantum limit [1 – 5]. Estimates show that these properties should make it possible for such a filter to separate (against the background of a strong illumination like the solar disc or a high-temperature plasma plume), amplify and record weak signals emitted by point sources and produced by only a few photons [2].

At the same time, an AQF is capable of amplifying signals within large solid angles determined by its geometrical parameters. The solid angle within which an AQF efficiently amplifies a signal at an almost constant gain may be tens of thousands times larger than the solid angle of diffraction. Hence, it is expedient to explore the possibility of using AQFs for image intensification.

In order to justify such a possibility of practical application of AQFs, one should determine in direct experiments whether the image brightness can be intensified in a real AQF without any deterioration of the quality of diffraction-limited resolution.

## 2. Experiments on image intensification of objects in an iodine AQF

Experiments were carried out in an iodine AQF pumped by the radiation from a coaxial cavity lamp with a stabilised discharge. To improve the optical homogeneity of the active region, an optical filter cutting off radiation at wavelengths smaller than 200 nm was placed between the cell containing the active gas and the inner wall of the cavity lamp. The discharge circuit was made in such a way that the current in the lamp increased continuously and was nearly bell-shaped with a current half-period 60 μs at half-height. The AQF cell had an inner diameter 2 cm and contained the working substance $n$-$C_3F_7I$ under a pressure of 1.25 kPa. Under such a pressure, the pump intensity was nearly uniform over the cell volume.

Fig. 1 shows the optical schematic of the experiment. The radiation pulse from a master oscillator (*1 – 5*) was reflected from the spherical mirror (*9*) to the mask object (*7*) and then was incident on the spherical mirror (*8*) at a distance equal to double the focal length from the mask. Mirror (*8*) formed the 1:1 image of the mask at the centre of the AQF cell, which was then magnified by a factor of 5.8 by mirror (*10*) and transferred to a white matted screen (*13*) where it was recorded by video camera (*14*) sensitive at the wavelength 1.315 μm. Such a setup (with intermediate mask imaging at the centre of the cell) was chosen to minimise the effect of optical inhomogeneities emerging in the active region of the AQF on the image quality.

After intensification in the AQF, the radiation was not directed immediately to the video camera because it accumulates luminescence noise signal during the AQF operation, i.e., over a period of several milliseconds. If the radiation is sent directly to the camera, the luminescence emission would force the camera out of the dynamic range. Recording of the radiation reflected by screen (*13*) suppressed the signal by more than four orders of magnitude,

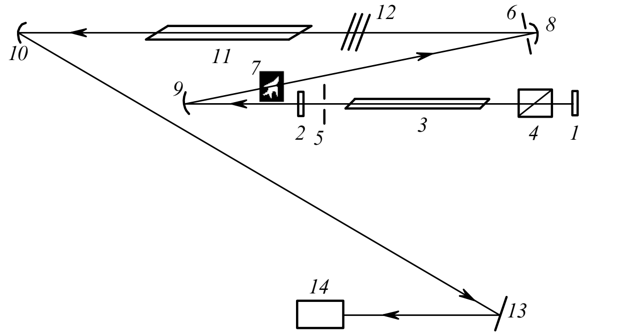


**Figure 1.** Experimental optical schematic: (*1, 2*) master oscillator mirrors; (*3*) master oscillator cell; (*4*) modulator; (*5, 6*) diaphragms; (*7*) mask object; (*8 – 10*) spherical mirrors ($F = 75$ cm); (*11*) AQF cell; (*12*) neutral optical filters; (*13*) screen; (*14*) video camera.

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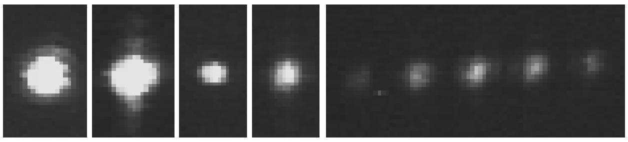
and the luminescence intensity did not exceed the noise signal of the camera itself. Such an optical scheme did not allow us to detect extremely weak signals, but made it possible to study the image intensification in the presence of optical inhomogeneities arising in the active region during the operation of a real AQF.

A diaphragm (*6*) of diameter 1 cm was placed in the vicinity of mirror (*8*) . The magnitude of resolution was determined by diffraction from this diaphragm. The diameters of the AQF cell and mirror (*10*) were much larger than that of diaphragm (*6*).

We performed experiments in the following sequence. The quality of the optical path was verified in the beginning. For this purpose, the mask object (*7*) was chosen in the form of a circular diaphragm of diameter 0.2 mm, which corresponds to the size of the diffraction spot at a distance of 150 cm from the spherical mirror (*8*) for a diameter 1 cm of diaphragm (*6*). The AQF pumping was not switched on, and the signal from the master oscillator was attenuated to the required level by using calibrated filters (*12*). The image of the diffraction spot recorded in this way is shown in Fig. 2a.



a b c d e

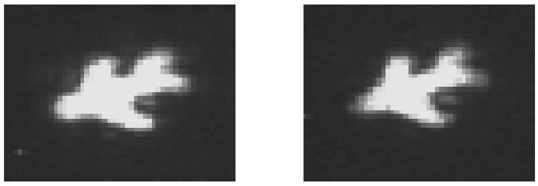
**Figure 2.** Image of a diffraction spot (a – d) and diffraction patterns of radiation diffracted from a grating with vertical slits (e) without (a, c) and with (b, d, e) AQF pumping.

Then, the signal was attenuated to 1/5000th of its magnitude by additional filters (*12*) and amplified in the AQF by a factor of 3000. The result is shown in Fig. 2b. The photographs in these experiments were specially overexposed in order to reveal the first diffraction ring in the Airy diffraction pattern. A comparison of the images in Figs. 2a and b shows that almost the diffraction-limited resolution was achieved in both cases. The diameters of the central peaks in the first and second images are almost identical, and only the intensity distribution in the first diffraction ring changes after intensification.

Figs. 2c and d show the images of two diffraction spots obtained in a similar way, but with a normal exposure. For this reason, the first diffraction ring in the Airy pattern is not observed.

To study the image intensification for a more complicated pattern, a grating with vertical slits (the grating period was 3 mm, and the slit width was 1.7 mm) was placed in the path of the beam reflected from mirror (*8*). Fig. 2e shows the series of the diffraction peaks recorded after intensification.

Having established that the intensification of a series of diffraction spots occurs virtually without any distortions, we performed the image intensification for a more complex object. The mask object with a circular aperture was replaced by a mask with an aeroplane-shaped hole. The angular dimensions of the object were as follows: the length of the mask was equal to seven times the diffraction-limited sizes, and the wing span was five times the diffraction-limited sizes. As in the preceding series, photographs were obtained without intensification and after attenuation followed by intensification. Fig. 3 shows the results.



a b

**Figure 3.** Image of a mask object in the form of an aeroplane silhouette without (a) and with (b) AQF pumping.

A comparison of the photographs in Figs 3a and b shows that the image of a quite complex object remains virtually unchanged and can be identified easily after a 3000-fold intensification in an iodine AQF. Slight distortions which are observed nevertheless, can be attributed to the fact that the exposure time in Fig. 3b was 1.7 times shorter than for Fig. 3a, because the radiation was attenuated by a factor of 5000 for the first image, and by a factor of 3000 for the second.

## 3. Conclusions

The experimental study of the possibility of using an AQF based on iodine photodissociation laser for 3000-fold image intensification by retaining the diffraction-limited resolution has shown that an iodine AQF can be used for efficient image intensification of point objects as well as objects of quite complex shape. The experiments carried out by us suggest that it is expedient to use an iodine AQF for laser ranging and laser probing, especially in the case of strong background illumination.

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