# RESOLVING POWER AND RECONSTRUCTION OF IMAGES IN A WFR MIRROR WITH THE FEEDBACK LOOP

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*Received June 26, 1993*

*In this paper we present experimental results on measuring the resolving power of a WFR mirror based on a degenerate four–photon interaction with a feedback loop in a photorefractive crystal. Experimentally obtained values of the resolving power of from* 30 *to* 45 grooves/mm, *under different conditions in the feedback loop well agree with independent data and theoretical calculations for a classical arrangement of the degenerate four–photon interaction. It is shown in the paper that a suppression of the generation of irreversed waves in the feedback loop provides for an increase of the resolving power. Influence of phase distortions of the incident beam on the resolving power is studied experimentally and good agreement with the theoretical estimates known from literature is obtained.*

The WFR mirrors, i.e., devices reversing the wave front of optical radiation are quite promising for transmitting an image and compensating for phase distortions in optical beams. In this connection the scheme of wave front reversion (WFR) based on a degenerate four–photon interaction (DFPI) with a feedback loop is of main interest.[1] It combined advantageously a nonthreshold, with respect to a signal–wave power, reversion and simple tuning. The examination of this scheme in different nonlinear media revealed that one of the most promising media for DFPI with a feedback loop are the photorefractive crystals.[2] However in the majority of papers devoted to this problem the emphasis was on energy and temporal characteristics of a WFR mirror. It should be noted that the problems related to investigating the WFR mirror as an optical system, i.e., determining its resolving power are also of interest here since its value is closely related to the problems on possible compensation for phase distortions introduced into the beam as well as on the maximum permissible size of inhomogeneities which can be compensated for with such a system. The experimental studies of WFR mirrors using a classical scheme of DFPI were undertaken in Refs. 3 and 4. The problem on resolving power of the system with a feedback loop has not been studied sufficiently well either experimentally or theoretically, though in Refs. 1 and 5 the authors discussed possible degradation of the WFR accuracy in a loop scheme due to a noise character of excitation of the second reference beam.

This paper describes an experimental study of the image resolving power and reconstruction ability of a WFR mirror based on DFPI with a feedback loop.

The general configuration of the experimental setup and wave vectors of interacting waves are depicted in Fig. 1. A single–mode parallel beam $L1$ of 6 mm diameter ($\lambda$ = 440 nm) illuminated a transparent *1* and was directed to the WFR mirror with a telescope *4*. A nonlinear medium where DFPI was accomplished was a photorefractive crystal *5* of strontium–barium niobate $Sr_{(1-x)}Ba_xNb_2O_6$ (SBN). The beam $L1$ passed through the crystal, then directed by mirrors *6* and *7* to it again as a beam $L3$. A grating of the refractive index is induced in the medium in directions $L2$ ($\mathbf{k}_{L2} = -\mathbf{k}_{L1}$) and $L4$ ($\mathbf{k}_{L4} = -\mathbf{k}_{L3}$) by the available noise scattered radiation together with the waves $L3$ and $L1$. Diffraction of the waves $L3$ and $L1$ on this grating provides for the beams $L2$ and $L4$ reversed with respect to $L1$ and $L3$. The wave $L4$ reflected from mirrors 7 and 6 is converted into the wave $L2$ thus closing the feedback loop. In Fig. 1*b* the directions of wave vectors of the given beams $L1$ and $L3$ are shown with solid lines, and those of the beams $L2$ and $L4$ excited during the DFPI process are given with dashed lines.

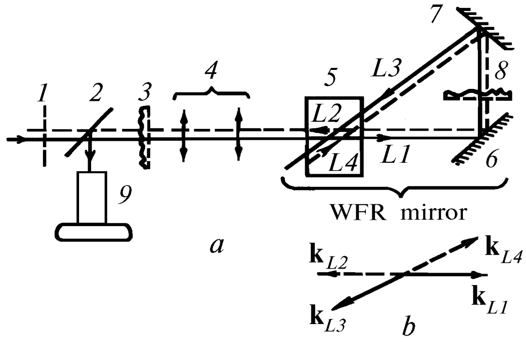

*FIG. 1. Block diagram of the experimental setup (a) and wave vectors of interacting waves (b).*

To record the reversed beam $L2$ carrying a transparent image a portion of it was branched off with a plate *2* to a photographing system *9* whose resolving power of 80 grooves/mm exceeded the one of the system under study. In quantitative measurements the transparent was a standard mira with the grooves density from 25 to 100 grooves/mm. For qualitative illustrations we used photopositives with a dashed image. The transparent image *1* reconstructed in the reversed beam was localized in a plane conjugated with the transparent plane. Phase distortions were introduced into the beam incident onto the WFR mirror using a phase plate *3* and in the feedback loop they were introduced using a plate *8*.

The WFR mirror resolving power was measured as a function of: 1) the parameters of the feedback loop such as its length and the presence of phase distortions on the beam

0235-6880/93/12 907-02 $02.00

path in the loop; and 2) the presence of random phase inhomogeneities in the beam incident on the WFR mirror. Based on variation of the resolving power in the second case it was possible to judge on the possibility of compensating for phase distortions with a WFR mirror.

Let us first describe the main energy and temporal characteristics of the WFR mirror under study. The reflection coefficient of the WFR mirror $R$ was 35–37%. This value of $R$ was not attained instantaneously but during some interval of time whose duration depended on the power $P$ of the beam incident on the system: when $P = 3$ mW the time of formation of the reversed response was 12–15 s and when $P$ decreased to 0.5 mW it increased to 40–50 s.

The resolving power of the WFR mirror, $F$, was measured for three values of the feedback loop length $l$: 32, 45, and 65 cm. The related values of $F$ proved to be equal to 30, 35, and 40 grooves/mm. Despite the small range of variations of $l$ (its further increase was limited by the fact that the system became highly sensitive to vibrations), these results show that the value $F$ also increases with the $l$ increase.

For the same values of $l$ the value $F$ was measured in the presence of random phase inhomogeneities in the loop which were introduced to the beam path with the phase plate *8*.

For all of the three $l$ values the resolving power $F$ increased of 5 grooves/mm when phase plate was introduced, and was 35, 40, and 45 grooves/mm for $l = 32$, 45, and 65 cm, respectively.

The aforementioned results are related to the case where the beam incident on the WFR mirror is close to a single–mode one. The resolving power of the WFR mirror became somewhat lower and was equal to 25 grooves/mm when random phase inhomogeneities with a characteristic size of 0.3 mm were introduced into the beam by phase plate *3*. When the characteristic size of inhomogeneities decreased to 0.07 mm no reconstruction of the mira image in the reserved beam was observed. Similarly, when observing reconstruction of the photopositive dashed image in the reserved beam, the introduced inhomogeneities with the characteristic size of 0.3 mm turned out to negligibly deteriorate the pattern quality. The decrease of the size of inhomogeneities to 0.07 mm resulted in sharp deterioration of the image quality.

It follows from the results obtained that in the absence of phase distortions in an incident beam the resolving power of the WFR mirror with a feedback loop is not lower than 30 grooves/mm. It is interesting to compare this value with the resolving power of the WFR mirror based on a classical arrangement of the degenerate four–photon interaction, since the interaction scheme is similar in both these cases and the basic difference is in the method of forming reference beams. The experimental resolving powers of WFR mirrors based on DFPI obtained by other authors were 40, Ref. 6, and 30 grooves/mm, Ref. 4. The agreement between these values and those described in this paper confirms the fact that the value of resolving powers of both schemes is substantially determined by the common factors including primarily the aperture effects. The theoretical estimate of resolving power of the classical DPFI scheme of 30 grooves/mm obtained in Ref. 4 taking into account the aperture effects is in good agreement with the experimental results obtained in our experiments and in Ref. 6.

In parallel with the common characteristics of the two systems, the system with a feedback loop has its own peculiarities which affect the inversion accuracy and are caused by self–excitation of the second reference beam. As noted[1,5] excitation in the feedback loop can lead, in addition to a phase–conjugated wave, to "noise" in the refractive–index grating and hence to worsening the inversion accuracy. Consequently, the conditions facilitating the excitation of a Gaussian beam being a phase–conjugated wave in the loop and the suppression of irreversed components should lead to an increase of the resolving power. Our experimental results agree well with what has been said above. Thus the increase of the feedback loop length which, as known, makes selection of a transverse mode easier, resulted in a substantial increase of $F$ from 30 to 40 grooves/mm. A phase plate, if placed in the loop, also makes the separation out of a phase–conjugated component easier, that, as seen from our measurements, increases $F$ of about 5 grooves/mm at a fixed length of the loop. The maximum resolving power of 45 grooves/mm was reached in our experiments with the feedback loop length of 65 cm with a phase plate in it.

To interpret the results on compensating for phase distortions in an incident beam it is expedient to use the results from Ref. 3. It was shown in this paper that the possibility of compensating for inhomogeneities is determined by the relation $\gamma = F^2 a^2/4\pi^2$ between the WFR mirror resolving power $F$ and the characteristic size of a medium inhomogeneities $a$. In particular, as long as $\gamma \geq 1$ the inhomogeneities introduced must be compensated for; when $\gamma \ll 1$ the efficiency of a compensating system decreases sharply. The experimental data described in this paper are in a good agreement with these calculations: for $a = 0.3$ mm ($F = 30$ grooves/mm) the value $\gamma$ is approximately equal to 2 and inhomogeneities in the incident beam were almost entirely compensated for; when $a = 0.07$ mm, $\gamma \sim 0.1$ and there were no compensation for the introduced distortions.

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