INTERNAL WAVE FOCUSSING BY HORIZONTAL OSCILLATIONS OF A TORUS

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Summary This paper presents an experimental study of internal waves generated by a horizontally oscillating toris in a linearly stratified fluid. 3D internal wave fields are reconstructed via measurements of vertical displacements of thin fluorescein layers with subpixel accuracy. It is shown that wave amplitude is strongly amplified in the focal region due to geometric focusing, and, locally, due to nonlinear effects. At large amplitude of oscillations overturning events are observed in the focal region.

INTRODUCTION

The interaction of the tidal motion with the ocean bottom topography is continuously generating internal waves [1, 2]. There is a reasonable agreement about the global rate of energy conversion from barotropic to baroclinic tide, which is estimated to be around 1TW [2]. The physics of internal wave generation has been studied in some detail for obstacles of simplified geometry including circular cylinders [3, 4] in two dimensions, and sphere in three dimensions [5, 6, 7]. Much less in known on conversion of internal wave energy to overturning, mixing and small-scale dissipation. Several scenarios are considered for energy concentration in localized zones representing hot spots for incipient overturning: nearly critical reflection at continental slope, energy concentration at attractors, internal wave refraction at horizons of high density gradient, interaction of wave beams, geometric focusing by 2D and 3D topography [8]. In this paper we explore the latter mechanism. We present an experimental study of internal waves generated in a linearly stratified fluid by horizontal oscillations of a torus having a vertical axis of revolution. The interest of such a configuration is that the internal waves converge to a focal region, modelling a situation that could be met for curved ridges of underwater mountains. Also, the toroidal geometry offers a link between a quasi 2D problem close to the torus surface and a fully 3D problem in the focal region. We use the technique described in [6, 7] to measure the evolution of the 3D distribution of wave amplitude with distance from the ring and with amplitude of oscillations to identify the regions of local wave amplification and/or breaking.

EXPERIMENTAL SETUP

Experiments were conducted in a plexiglas square tank of depth 100cm and horizontal dimensions 100x100cm. The scheme of the experimental setup is shown in figure 1. The tank was filled with a linearly salt-stratified fluid. The buoyancy frequency was kept constant at $N = [-(g/\rho)(d\rho/dz)]^{1/2} = 0.72\ s^{-1}$, where $\rho(z)$ is the density distribution over the vertical coordinate z, g is the gravity acceleration. The internal waves were generated by a horizontally oscillating torus attached to the end of a pendulum of length $l = 1.3m$.

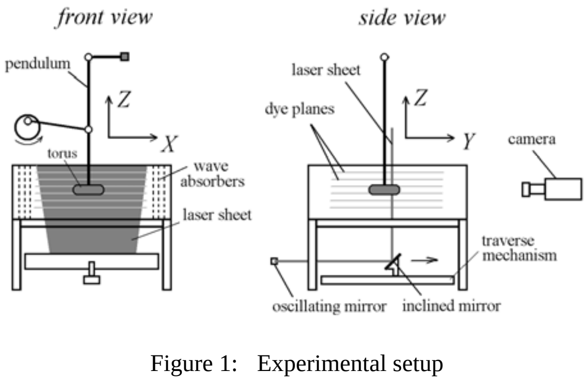

Figure 1: Experimental setup

The shape of the generatrix of the torus was circular, with diameter $2a = 4cm$ .The mean radius of the torus was $R=5a$. The oscillations of the pendulum at frequency ω were driven by a crank mechanism. The wave visualization and data processing were performed with the help of technique described in [6, 7]. To reconstruct the 3D distributions of the wave amplitude the position of the laser sheet was changed with a prescribed increment by moving the mirror reflecting the laser light in vertical direction. The vertical displacements of dye planes were estimated and the amplitudes of the harmonic components of the signal $|\zeta_n^a|$ were determined via Fourier filtering. The corresponding non-dimensional quantities are introduced as $|\zeta_n^a|/A$.

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EXPERIMENTAL RESULTS

The experiments were conducted at $\Omega = \omega/N = 0.81$ for the following set of non-dimensional amplitudes of oscillations: $A/a = 0.13$; 0.29; 0.5; 0.6; 0.82. It is found that as the amplitude of oscillations increases, the profiles of the first harmonic wave undergo nonlinear transformation as shown in figure 2.

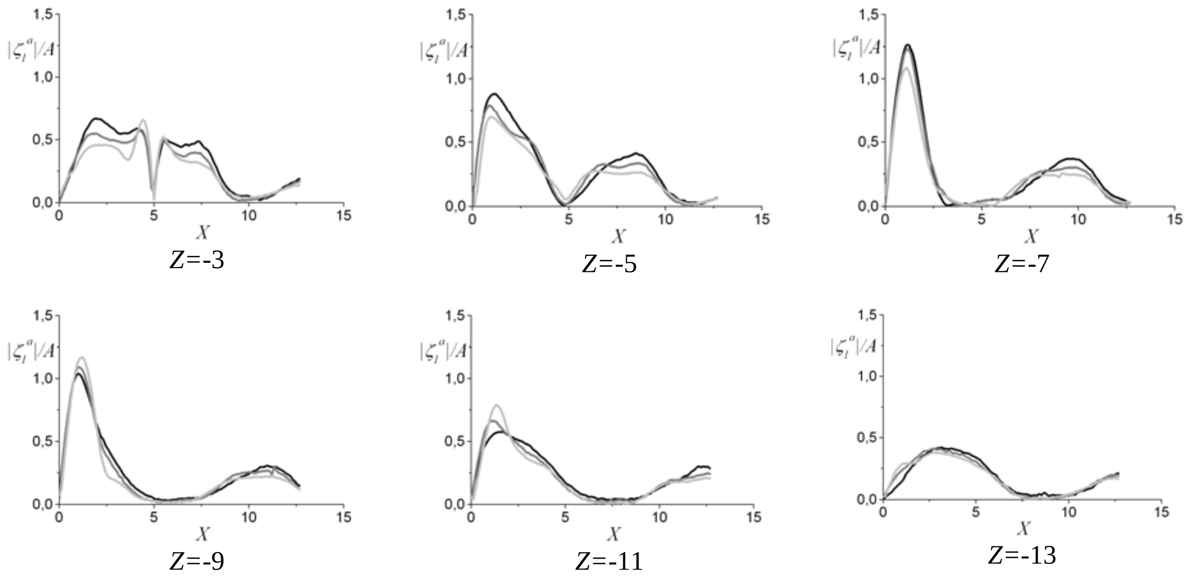

Figure 2: Evolution of the normalized wave amplitude with amplitude of oscillation *A/a* and distance from the torus *Z*. Black, dark grey and light grey lines correspond to *A/a*= 0.13; 0.29 and 0.5. Envelopes are obtained for the vertical plane passing through the centre of the torus. X-direction corresponds to the direction of oscillations. .

It can be seen that in the focal region (see results for *Z*=-9 and *Z*=-11 in figure 2) in a local range of *X* between 0 and 2 the trend toward nonlinear amplification is detectable. The same trend is observed near the ring (*Z*=-3) at *X* close to 5. The distributions of wave amplitude in planes XY and XZ (the direction of the axes is shown in figure 1) are not shown here because of limitations on the paper length. The localized trends toward amplification favour the growth of local wave steepness and onset of overturning. Local overturning due to hydrostatic instability is observed in the regions of non-linear wave amplification at $A/a \geq 0.6$. This type of instability seems to be the most important one in relation to incipient mixing for the experimental setup considered.

CONCLUSIONS

In this paper we present an experimental study on the theoretical scenario described in [8]. In addition to the purely geometric focussing of internal waves emitted by horizontal oscillations of a torus we observe non-linear wave amplification in the focal region and close to the torus. Regarding geophysical applications to baroclinic tides, the results of the present study suggest enhanced conditions for internal wave overturning and mixing at concave side of underwater mountain ridges.

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