# Generation of focalized wave packet.

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## 1) Introduction

The generation of focalized wave packets is studied both experimentally and numerically. The experimental campaign is carried out in the wave flume of Ecole Centrale Marseille. The purpose is to experimentally generate the focalisation of wave close to a vertical wall thus yielding a database for numerical tools.

Two numerical approaches are investigated. The theoretical framework is potential theory. On one hand Boussinesq equations are solved. Initial state of the free surface is hence first determined. To this end the wave elevation close to a wavemaker is either measured from experiments or calculated from a classical linear model. Boussinesq model is suitable to propagate adequately a wave packet by accounting for most nonlinearities of the gravity wave. From that model, initial conditions are extracted and introduced in a fully nonlinear wave model.

The present abstract shows some results illustrating the techniques developed and their validations. Scale effects in experiments are commented. Difficulties to reproduce numerically the fine details of the measured overturning crest at the vertical wall are discussed.

## 2) Numerical tools

Boussinesq model follows from the theoretical developments of Bingham *et al.* (2009). This approach has been successfully used for many applications (Fuhrman *et al.*, 2006; Jamois *et al.*, 2006; Fuhrman and Madsen, 2008).

The present fully nonlinear wave model follows from the theoretical developments by Krasny (1985) and Tuck (1997). It has been already presented in Scolan *et al.* (2007) and quite similar works are shown in Bredmose *et al.* (2007). The tank is basically rectangular and filled with a liquid up to a moving free surface. In order to reduce as much as possible the numbers of unknowns, the boundary conditions on impermeable and fixed boundaries are accounted for by introducing a Green function which satisfies those boundary conditions. To this end conformal mapping are used. The physical domain is described by the complex number $z$ and its transformed complex coordinate is $w$. These numbers are linked by the relation $w = -\cos\frac{\pi z}{L}$ and the fluid is now contained in the upper half $w$-plane; the real axis $\Im w = 0$ thus being the impermeable walls. The complex potential of any flow in this half plane can be described by means of sources arranged in a suitable way. The elemental complex potential of a source located at $w = \omega$ behaves as $F = \log(w - \omega)$. Here a desingularized technique –as proposed by Krasny (1985)– leads to place sources at a small distance $\epsilon$ in the normal direction from the actual position of the free surface. The resulting velocity potential concatenates the influence of a large enough number (noted $N$) of such sources

$$\phi(x,y,t) = \sum_{j=1}^{N} q_j(t)\left(\log\Big[w(x,y) - \omega(X_j(t), Y_j(t), \epsilon)\Big] + \log\Big[w(x,y) - \overline{\omega}(X_j(t), Y_j(t), \epsilon)\Big]\right) \qquad (1)$$

where $(X_j(t), Y_j(t))$ are the source location at time $t$ in the physical $z$-plane and $q_j$ is the strength of source $j$. The overline denotes the conjugate of a complex number. The numerical experiments show that $\epsilon = \frac{L}{2N}$ is an "excellent arbitrary choice". The source intensities are calculated by solving the time differential system as follows

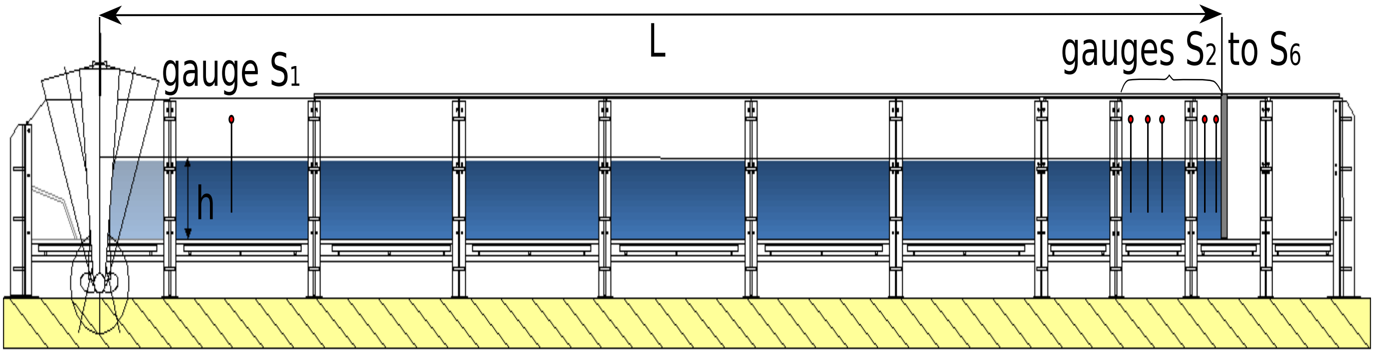
$$\frac{\mathrm{d}\phi}{\mathrm{d}t} = \frac{1}{2}(U^2 + V^2) - g(y - h), \qquad \frac{\mathrm{d}X}{\mathrm{d}t} = U, \qquad \frac{\mathrm{d}Y}{\mathrm{d}t} = V \qquad (2)$$

where $g$ is the gravity, $h$ the liquid depth and $\vec{\nabla}\phi = (U, V)$ are the cartesian coordinates of the velocity in the physical plane. A classical algorithm of Runge-Kutta (precise up to fourth order) is used to forward in time. The elaborated computational code is not only robust (no smoothing is required) but also needs few computational resources. As an example of the speedness of the algorithms, we evaluate the average CPU cost of a time step for 200 markers on the free surface: $T_{cpu\,\Delta t} \approx 0.19s$ on a standard processor. Half time is spent in routine for solving the linear system and some gain is still expected. Hence few seconds are needed to simulate a sequence and parametrical studies are feasible.

## 3) Experimental campaign

The experimental campaign is carried out in the flume sketched below. Two scales are studied:

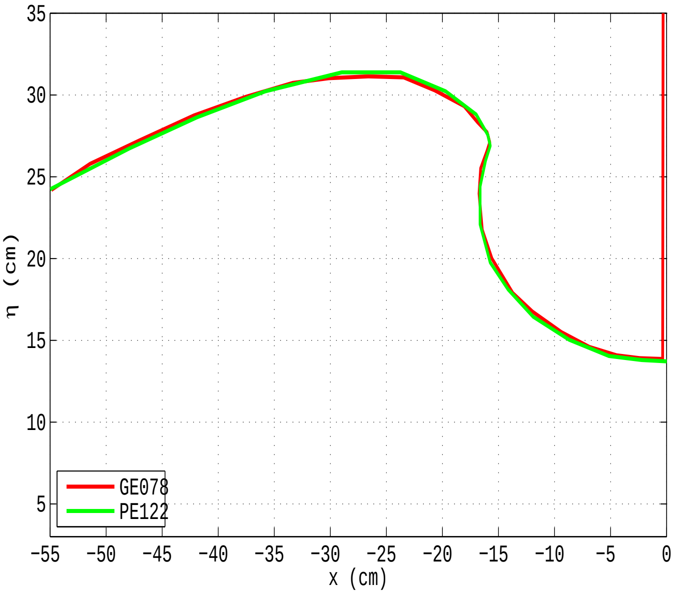
1. depth h=0.70m and focalisation distance L = 15.5m (scale = 1)
2. depth h=0.35m and focalisation distance L = 7.75m (scale = 1/2)

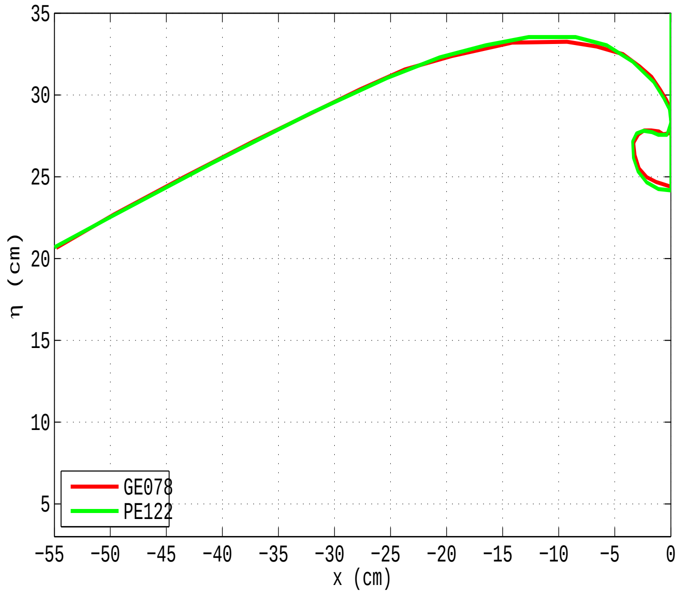



The generation of the focalized wave follows from a given focal point and a given spectrum. The chosen spectrum is a Ricker spectrum (actually the second derivative of a Gaussian function) :

$$R(\omega) = \sqrt{\pi}\, T\, e^{-\omega^2 T^2/4} \left(1 - a\left(\frac{1}{4}\omega^2 T^2 - \frac{1}{2}\right)\right) \tag{3}$$

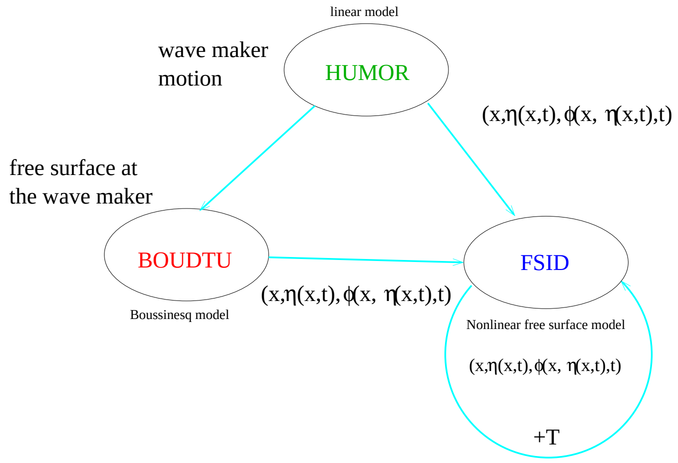
where $a$ and $T$ are parameters to tune in order to fit the peak frequency and the narrowness of the signal. This spectrum leads to good compromise in order to tackle a large range of overturning crest at the wall. To characterize the wave field, wave elevation is measured by means of six resistive wave gauges (their locations are specified in the figure above) and the surface elevation, near the plate, is caught by using a high speed camera (1000 frames/sec). Comparisons of the two scales are given below



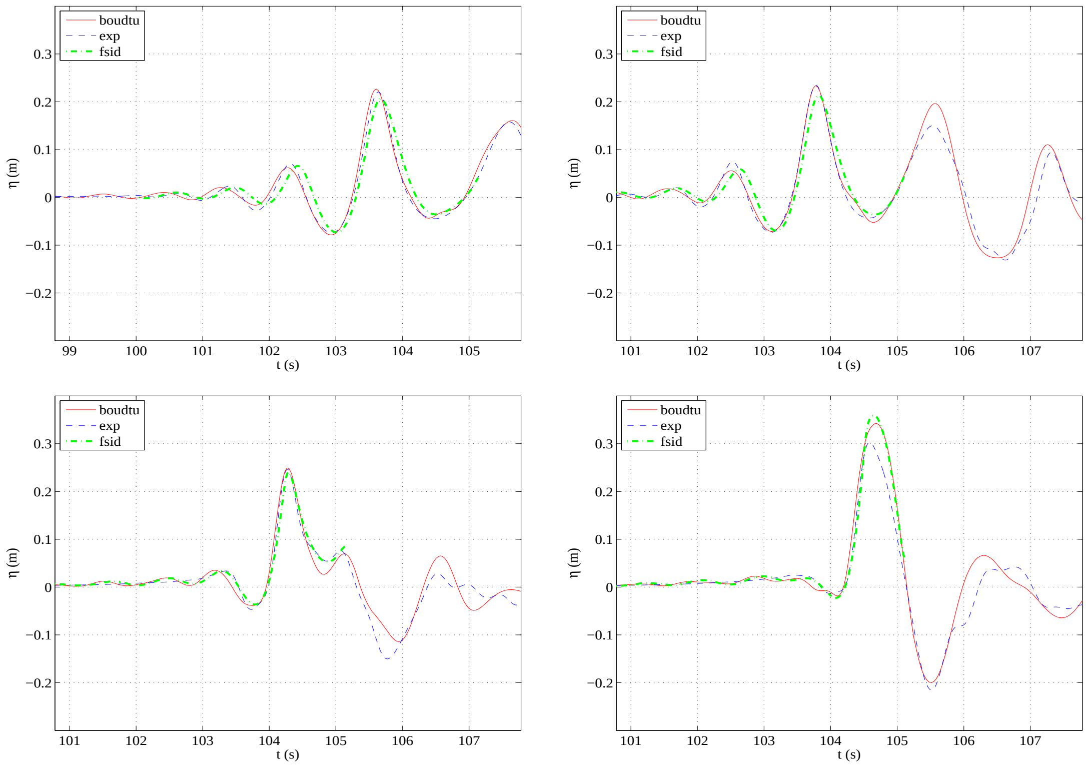
## 4) Applications

The communications between the different codes are sketched below




Boussinesq model provides a snapshot of the wave packet in the flume at a given time when the whole wave packet has been generated; the support of the free surface elevation is roughly compact. That is used as input data for the nonlinear model FSID. Restarts of this code can be performed in order to concentrate the computational efforts on the last stages of the focalisation.

We compare the different models which simulate the propagation. The time history of the elevation at four locations close to wall are drawn: $(L - x)/L = 0.1465$, 0.1245, 0.0516 and 0.0129.




Discrepancies increase at the last stages and that shows that the spectrum contents especially at the low frequency range may play a significant role. More insights into that problem are necessary. On the other hand we can use some artifacts which circumvent the difficulties. One of them is to tune the parameters of the nonlinear model so that the wave shape, as the wave arrives at the wall, is more or less reproduced. The question whether or not the shape of the wave is strongly related to the kinematics below the free surface, is still open. However it was shown that under some circumstances, those artifacts work and discrepancies are within the range of experimental uncertainties.

## 5) Conclusion

Wave focalisation process is elobarated in the wave flume of Centrale Marseille. It is shown that Ricker spectrum is suitable to cover a large range of overturning crest at the focalisation point. Experimental databases are hence built to test several numericals tools. Some difficulties associated to the generation of focalised wave have been identified. In particular the reproduction of fine details of the overturning crest at the expected focalisation point is still difficult.

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