# EFFECT OF INDUCED INTERFERENCE AND THE FORMATION OF SPATIAL PERTURBATION FINE STRUCTURE IN NONEQULIBRIUM OPEN-ENDED SYSTEM

*V.M. Kuklin*
*Kharkov State University, 4, Svobody Square, Kharkov, 61077, Ukraine*

It is shown, that the modes of unstable spectrum of instability near threshold are able to form long-living spatial fine structure and anomalous interference splashes, induced by the pump.

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## 1. INTRODUCTION

In this paper the three basic characteristics of the instability near threshold supported by external source in absorbing medium with cubic nonlinearity are discussed.

1. First of all, most if not all of types of interaction between modes (except a few types) of the perturbation spectrum is negligible [1-2]. An integral action on the pump by the perturbation spectrum is substantial to a great extent. Therefore a linear stage of the instability transforms to the so-called quasilinear stage. At that stage of instability process the integrated intensity of perturbation spectrum independently of its width. That intensity reaches (but not exceeds) some threshold level. From this moment the rate of change of their amplitudes (but not phases) becomes abruptly slower [3]. Deceleration is a result of depumping. The depumping occurs due to an integral action of the perturbation spectrum on pump. Hence the life time of the instability process is hundred or thousand times greater then a value of the inverse increment of linear theory. Under existing conditions the phases of perturbation spectrum modes locked by pump are able to form forced interference splashes, induced by pump. Incidentally, the noise level reduction [4] leads to a subsidiary deceleration of quasilinear stage of the instability in media with and without wave motion [3,5].

The behavior of the separate mode of spectrum $a_n = a(k_n)$ near the instability threshold can be described by the reductive equation

$$da_n / dt = [\gamma_L(k_n) - \delta\,]\cdot a_n - 2\sum_m |a_m|^2\, a_n\,, \qquad (1)$$

and at the same time $\gamma_L(k_n) \le \gamma_{LMAX}$. The quasilinear stage of instability starts with the achievement of the threshold intensity independently of the spectrum width:

$$(2\sum_{m\neq 0} |a_m|^2)_{THR} \approx D \propto [\gamma_{LMAX} - \delta\,], \qquad (2)$$

Where $\gamma_{NL} = \gamma_L(k_n) - \delta - 2\sum_m |a_m|^2$ is a nonlinear increment, $D$ is a level of an imperfection, which is a small parameter as well. At the quasilinear stage strong inequality $|\gamma_{NL}| << \gamma_L - \delta$ determines anomalous retardation of the instability process.

2. In the second place a slow change of the amplitudes of the unstable modes coupled up relatively fast behavior of the phases. The phase motion is able to form the interference splash or fine structure of the perturbation, induced by pump. This effect of the induced interference at the quasilinear stage of instability appears from the forced-phase locking by pump. Average amplitude of $N$-modes of the perturbation spectrum is $\overline{a_n} \propto a_0\sqrt{D}/\sqrt{N}$ and the wave amplitude in the area of the interference splash is able to reach a value $a_0\sqrt{D\cdot N}$. In case of $D << 1$ and $N >> 1$ the amplitude of the modulated wave in the area of the interference splash is a few times greater than such amplitude in ambient space [6,7].

3. Thirdly, on the quasilinear stage of instability the pumping intensity is slowly decreasing. The peripheral parts of the perturbation spectrum are putting down. Though some modes of the central parts of that spectrum keep slowly growing. Finally that process results in abnormal bandwidth narrowing of the instability and formation of the line spectrum of the mature structures [1,2].

In most cases near threshold of instability the quasilinear operation is realized and coupled with effect of induced interference. This mechanism is responsible for formation of the fine structure of the laser pulses and for formation of amplitude splashes as a result of the modulation instability of the finite amplitude wave [6,7]. Effect of induced interference will becomes apparent when development delay of instabilities takes a place. It is possible only near threshold of instabilities.

## 2. STRUCTURAL TRANSITION IN CONVECTIVE INSTABILITY

Let us discuss the process of convective selection in the framework of the weakly nonlinear theory. To keep the computations simple, we shall work with the Proctor-Sivashinsky model [8,9] supplemented by external forcing

$$\dot{\Phi} = \varepsilon^2\Phi - (1-\nabla^2)^2\Phi + \frac{1}{3}\nabla\left(\nabla\Phi\,|\Phi|^2\right) + \varepsilon^2 f\,, \qquad (3)$$

where the Rayleigh number Ra is close to the critical value $Ra_c$ corresponding to the onset of convective flow $Ra = Ra_c(1+\varepsilon)$.

This equation describes the two-dimensional temperature field $\Phi$ in the horizontal plane ($x$,$y$) generated by the thermal convection in a layer of Boussinesq fluid between poorly conducting horizontal planes. For $\varepsilon << 1$, the solution of the unforced equation (1) is given by the mode combination

$$\Phi = \varepsilon\sum_j a_j \exp(ik_j r) \qquad (4)$$

with $|k_j| = 1$. The amplitude equations governing the slow evolution of the amplitudes $a_j$ (on the temporal scale extended by the factor $\varepsilon^{-2}$) have the form [10].

$$\dot{a}_j = a_j - \sum_{i=1}^{N} V_{ij}\,|a_i|^2\,a_j\,. \qquad (5)$$

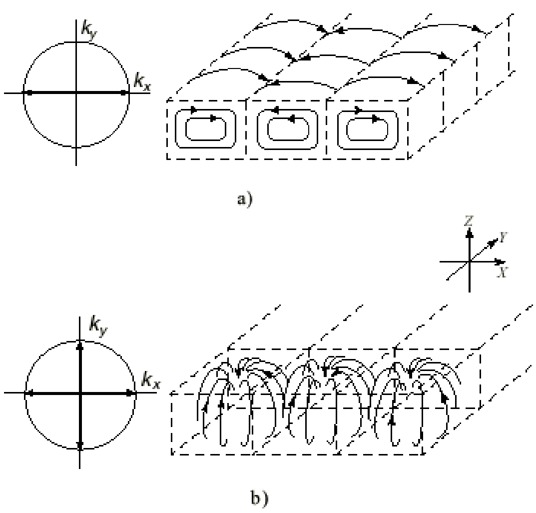



*Fig.1. Convective structures corresponding to the quasi-stable rolls (a) and stable cells (b)*

Coupling factors have the form

$$V_{jj} = 1\,,\; V_{ij} = 2/3\left(1 - 2\left(k_i k_j\right)^2\right) = 2/3\left(1 + 2\cos^2\theta\right), \qquad (6)$$

where $\theta$ is the angle between the vectors $k_i$ and $k_j$.

As a rule, in the beginning the simplest structure – convective rolls will appear in the system (Fig.1,a). In this case the amplitude of the mode $a_1$ considerably exceeds the amplitudes of other modes.

The state with $N = 1$ does not appear generally. In real systems at first the short-lifetime structure is formed – imperfect rolls, which are weakly modulated in direction of their orientation. This structure connects the mode $a_1 = a(\theta = 0)$ with comparatively large amplitude and the narrow spectrum of modes with small intensity, which is located close to $\theta = \pi/2$. Determine the intensity of this spectrum as

$$A = \sum_{\theta_i \neq \pi/2} a^2(\theta_i)\,, \qquad (7)$$

where the central mode $a_2 = a(\theta = \pi/2)$ is excluded from the sum. It may be shown that the narrowing of the spectrum in a vicinity of $\theta = \pi/2$ occurs.

The set of equations approximating the above-described behavior of the system (when one of the modes ($a_1$) turned out to be sufficiently large) may be written in the form

$$\dot{a}_1^2 = 2a_1^2\left[1 - a_1^2 - \frac{2}{3}a_2^2 - \frac{2}{3}A\right], \qquad (8)$$

$$\dot{a}_2^2 = 2a_2^2\left[1 - \frac{2}{3}a_1^2 - a_2^2 - 2A\right], \qquad (9)$$

$$\dot{A} \approx 2A\left[1 - \frac{2}{3}a_1^2 - 2a_2^2 - 2A\right]. \qquad (10)$$

Let us assume that the central mode of the spectrum $a_2 = a(\theta = \pi/2)$ is insignificant and consider that the growth of the primary mode $a_1 = a(\theta = 0)$ is slowing down. Than we obtain $A \to 3/14$, $a_1^2 \to 6/7$. Subsequently the behavior of the spectrum $A$ and the central mode $a_2$ may be described by the equations

$$Y' = Y\left(1 - \frac{14}{5}X - Y\right), \qquad (11)$$

$$X' = X(1 - X - Y)\,, \qquad (12)$$

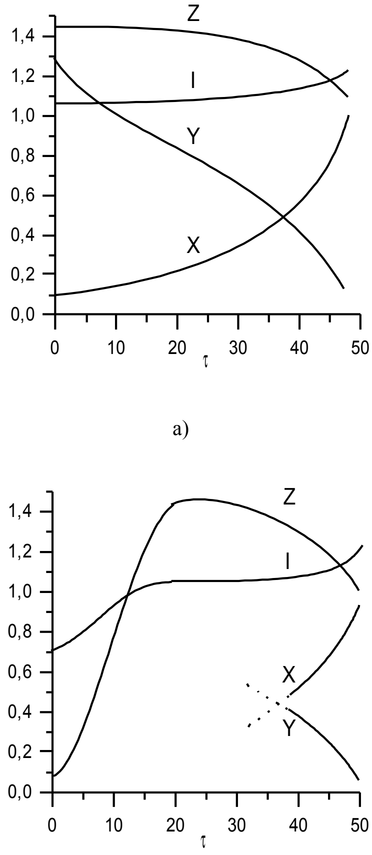
where $Y = 14A/3$, $X = 5a_2^2/3$, $X' \equiv dX/d\tau$, $\tau = 1.5t$, besides determine $Z = 5a_1^2/3$, which fulfills the following expression:

$$Z = \frac{5}{3} - \frac{2}{3}X - \frac{5}{21}Y\,. \qquad (13)$$

The intensity of the structure $I = \sum_j a_j^2$ may be written in the form

$$I = \frac{3}{5}\left[X + Z + 5Y/4\right]. \qquad (14)$$

Note that each state has it's own value of the structure intensity. The perfect structures – convective rolls and cells (i.e. perpendicular oriented rolls), have the intensity equal to 1 and $6/5$ respectively. The intermediate state with short lifetime – the imperfect rolls, has the structure intensity 15/14. Fig.2,a shows the evolution of the system, governed by Eqs. (8)-(10). It is easy to see the formation of the intermediate state – the imperfect convective rolls with structural intensity $I \approx 15/14$ ($Y(0) = 1.27$).




b)

*Fig.2. a) Dynamics of the system, calculated by Eqs. (9)-(10); b) the direct solution of Eq. (3) with initial conditions , , where $i_{max}$ = N =50, the spontaneous external noise*

Eventually this intermediate state is broken and the perfect structure – regular cells is formed (Fig.1,b). Direct solution of Eq. (3) with initial conditions $a_1(t=0)=0.2$, $a_{i\neq 1}(t=0)=0.05$ (taking into consideration spontaneous external noise $|f_{\max}| \approx 0.3$) are shown in Fig.2,b, where the curves 1, 2, 3 correspond to the functions, defined after Eqs. (8)-(10). There is correspondence of the solution of the general Eqs. (3) and the solution of the modeling Eqs. (8)-(10).

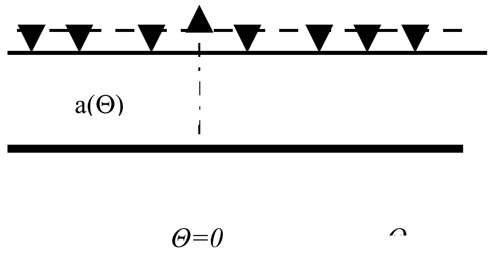



*Fig.3. Model of the mode competition in convection*

Thus, the primary instability causes the short-lifetime structure – the imperfect convective rolls. When the main mode amplitude $a_1$ is close to the critical value $a_{1cr} = \sqrt{6/7}$ and the spectrum intensity *A* becomes less than the threshold value $A_{thr} = 3/14$, the secondary instability arises and the central mode of the spectrum $a_2$ begins grow. The perfect structure – regular cells, appears as a result of this secondary instability. In that case the nonlinearity forms development delay of instabilities and the spectrum with trapped modes. A mode competition (Fig.3) results the slow changed two-dimensional spatial fine structure of the convection with great life time.

In the presence of an external noise or due to other reasons, which support the fluctuation in the system the structural rearrangement may take place. The noise level reduction leads to a subsidiary deceleration of the instability.

## 3. MODULATION INSTABILITY OF THE FINITE AMPLITUDE WAVE NEAR THRESHOLD

Let us assume that Lighhill equation [10] is correctly for slowly variable complex amplitude of the wave perturbation and it describes a nonlinear wave propagation

$$\frac{\partial A}{\partial t} = -\delta A - i\frac{\partial^2 A}{\partial x^2} - iA|A|^2 + g \qquad (15)$$

where $\delta$ is a decrement of oscillation damping, *g* is an external source, which supports the finite amplitude monochromatic wave *A* with the wavenumber $k = k_0$. The variables $t, x$ are the normalized time and coordinate, correspondingly. Let a main mode be $u_0 \exp\{i\varphi_0 - ik_0 x\}$, where $u_0 = A_{k_0}, \varphi_0 = \varphi_{k_0}$ is an amplitude and a phase of the wave. The main mode is a pump wave for the spectrum of the instable modes. The spectrum of oscillation $u_n \exp\{i\varphi_n - ik_n x\}$ is excited as a result of instability. This oscillation is connected with the main mode by the spatial synchronism conditions $2k_0 = k_n + k_{-n}$, where $k_{\pm n} = k_0 \pm K_n$, ($0 < K_n = K_{-n} << k_0$).

Let us note that the wave numbers of the instable modes are symmetrically distributed relatively to a wave number of the main mode. The amplitude of the main mode in these conditions is determined from the equation

$$u_0 = 1/\{1 + \frac{2}{\delta}\sum_{m>0}^{N} u_m{}^2 Sin\Phi_m\}. \qquad (16)$$

The summation here and below is carried out only with the positive indexes $m, n = 1,2,...N$, and $\Phi_n = 2\varphi_0 - \varphi_n - \varphi_{-n}$ is a phase of *n*-th channel of instability. Here $\Phi_0$ is not in existence and $\Phi_n = \Phi_{-n}$, $u_n = u_{-n}$ [1]. Let us assume for simplicity $\delta = g$. The requirement of closeness to threshold of instability leads to the small parameter

$$D = \frac{2}{u_0^2}\sum_{m>0}^{N} u_m^2, \qquad (17)$$

which at the same time define an imperfection *D* of the growing spatial structure [3]. The initial value of the phase of the main wave (*n* = 0) equals to zero. This phase is described by following equation

$$\frac{d\varphi_0}{dt} = +k_0{}^2 - u_0{}^2 - 4\sum_{m>0}^{N} u_m{}^2 - 2\sum_{m>0}^{N} u_m{}^2 Cos\Phi_m \qquad (18)$$

A change of the amplitudes of the growing modes is defined by equations

$$\frac{du_n}{dt} = u_n\{-\delta + u_0^2 Sin\Phi_n\}. \qquad (19)$$

It is obvious, that reversal of the sign of *n* doesn't change the equations. The phases of the modes depend on sign of *n*.

$$\frac{d\varphi_n}{dt} = k_n^2 - 2(u_0^2 + 2\sum_{m>0}^{N} u_m^2 - \frac{1}{2}u_n^2) - u_0^2 Cos\Phi_n \qquad (20)$$

For calculation it is necessary to know, how the n-th channel phase of instability is changing.

$$\frac{d\Phi_n}{dt} = \Delta_n + 2(u_0^2 - u_n^2) + 2(u_0^2 Cos\Phi_n - 2\sum_{m>0}^{N} u_m{}^2 Cos\Phi_m), \qquad (21)$$

where $\Delta_n = 2k_0^2 - k_n^2 - k_{-n}^2$. It is easy to see, that $\Delta_n = -2K_n{}^2$.

First of all let us note that for realization of the instability it is necessary at least that the phase of each n-th channel of instability $\Phi_n$ fast possesses the defined value $\Phi^*_n$. The phase of n-th channel of instability practically doesn't change and exponential growth of amplitude $u_n$ is beginning. Linear increment of instability is equal to

$$\mathrm{Im}\,\omega = -\delta + (-\Delta_n^2 - 4\Delta_n u_0^2)^{1/2}/2. \qquad (22)$$

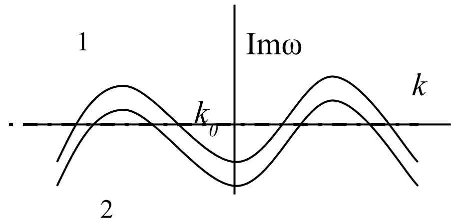



*Fig.4. Increment of modulation instability Imω as a function of wavenumber k for $\delta \neq 0$. 1.- t =0; 2.- t >0*

If $\Delta_n = -2u_0^2$, then increment reaches a maximum value which equals to $(1-\delta)$, where $0<\delta<1$. The interval of instability in the wave-vector space (Fig.4) is determined by the requirement $\mathrm{Im}\omega > 0$ and is specified by the following inequality $-2(1+\sqrt{1-\delta^2}) < \Delta_n < -2(1-\sqrt{1-\delta^2})$. The set of equations (16), (19), (21) describes the modulation instability in case of the small exceeding of the instability threshold (i.e. if $1-\delta << 1$). At the same time the phases are located in a neighbourhood of $\Phi^*_n$, which are slowly changing when the perturbation amplitudes grow up and the pump level is reduced. The equation (25) and (27) allow to receive information about the behavior of phase of separate interactive modes.

For clarification of a character of growing spatial modulation of the main wave let examine an approximation theory, when the changes of phases $\Phi_n = \Phi^*_n$ are neglected. In that case one may use a small parameter (6) in order to receive the following expression for $Cos\Phi_n, Sin\Phi_n$

$$Cos\Phi_n = -[\Delta_n + 2(u_0^2 - u_n^2)]/2u_0^2; \quad (23)$$
$$Sin\Phi_n = (-\Delta_n^2 - 4u_0^2\Delta_n)^{1/2}/2u_0^2.$$

This expression of the trigonometrical functions allow to find the equations for an amplitude

$$u_0 \approx \{1 - \frac{2}{\delta}\sum_{m>0}^{N} u_m^2\}, \quad (24)$$

and a phase main mode

$$\frac{d\varphi_0}{dt} \approx k_0^2 - u_0^2 - 4\sum_{m>0}^{N} u_m^2, \quad (25)$$

For amplitude and phase of the growing modes the following equations are valid

$$\frac{du_n}{dt} = u_n\{-\delta + \frac{1}{2}(-\Delta_n^2 - 4\Delta_n)^{1/2} - \frac{4}{\delta}\sum_{m>0}^{N} u_m^2\}; \quad (26)$$

$$\frac{d\varphi_n}{dt} = k_0^2 - u_0^2 - 4\sum_{m>0}^{N} u_m^2 + 2\frac{n}{|n|}k_0\sqrt{\frac{|\Delta_n|}{2}}. \quad (27)$$

The expression for modulated wave in the conditions of developed instability in that approximation is represented in the form

$$E(x,t) = \exp\{-ik_0x + i\varphi_0(t)\}\cdot[u_0 + + \sum_{m>0}^{N} u_m \exp\{i\Phi_m/2)\}Cos\{K_m\xi - (\varphi_{m0} - \varphi_{-m0})/2\}], \quad (28)$$

where $\varphi_{m0} = \varphi_m(t=0), \varphi_{-m0} = \varphi_{-m}(t=0)$ – initial phases of the modes, $\xi = x - 2k_0t$.

Thus a second item in (28), i.e. a modulation of the main wave, represents a sum of periodic perturbation with a wave-length equal to $2\pi/K_n = 2\pi(2/\Delta_n)^{1/2}$, which is in $k_0/K_n = (2k_0^2/|\Delta_n|)^{1/2}$ times greater then a length of the main mode. It is important that in this approximation all perturbations don't shift one relatively another.

Modes with the wave numbers $k_n = k_0 + K_{N/2}$ and $k_{-n} = k_0 - K_{N/2}$ offers the largest linear increment. On instability development the pump level decrease, effective increments of the rest of modes decrease and change into decrements. All that processes follow from the equations (16)-(27). Thus, the mode competition due to mechanism of "pump depletion" results in the bandwidth reduction of developed instability.

The slow change of channel phase (i.e. $d\Phi_n/dt \neq 0$) account for slow relative motion of perturbation with different wave-length (see the second item of (28)). Let us examine the process of splash formation of modulated wave amplitude. It follows from equation (19) that exponential growth of the amplitudes of instability spectrum stops when a second item of equation is approaching zero. A1so $D(\delta)$ is some value, more less than unit. At that moment the modulated wave (28) is formed. Modulated wave is composed of the main mode and a set of long-wave perturbations, which slowly shift one relatively another. A rate of instability evolution becomes slower sharply and the modes in the outlying parts of spectrum, which are long-wave and short-wave parts of spectrum, decrease their own amplitudes. The modes from a band center are slowly increasing. The instability spectrum gradually converges.

It is important to note that at a quasilinear stage of instability with decreasing number of modes *N* or spectrum width $\Delta K$ the equation (18) practically doesn't change. An average value of the mode amplitudes of instability spectrum rises. In case of discrete spectrum the expressions $2N\cdot(u^2)_{av} \approx D$ and $\bar{u} = \sqrt{(u^2)_{av}} \propto (D/2N)^{1/2}$ are valid. In certain spatial domain will be formed a splash of modulated wave with an amplitude $N\cdot\bar{u} \propto \sqrt{N\cdot D/2}$. Is it possible to estimate a time of splash formation $\tau$ as

$$\tau \propto 4\pi/[(d\Phi/dt)_{\max} - (d\Phi/dt)_{\min}]. \quad (29)$$

To imagine the pattern of splash, one may use an approximation at the beginning of quasilinear stage of instability

$$2\sum_{m=1}^{N} u_m^2 = \frac{N}{\Delta K}\int dK\cdot\frac{D}{N}\exp\{-2\frac{(K-K_{N/2})}{\Delta K}\}, \quad (30)$$

where $K_{N/2}$ is a central mode of modulation spectrum, $\Delta K$ is a spectrum width, $\delta K \propto \Delta K/N$ is a spectral width of a single mode. The expression (20) corresponds to an equality $2N\cdot(u^2)_{av} = D$. In the presence of induced interference the amplitude of modulation is given by

$$(N/\Delta K)\int(D/N)^{1/2}\exp(-|K-K_{N/2}|/\Delta K)\times \times Sin(K\cdot x)dK = \sqrt{D\cdot\Delta K}\cdot\frac{Sin(K_{N/2}\cdot x)}{(\Delta K)^2\cdot x^2+1}. \quad (31)$$

For modulation instability even under the small threshold crossing, the spectrum width $\Delta K$ is insignificantly smaller then the wavenumber of a rapidly growing modulation $K_{N/2}$. The most intensive splash is observed on a spatial interval $\Delta x \propto 1/\Delta K \propto 1/K_{N/2}$, which is visibly less, then an average length of modulation $2\pi / K_{N/2}$ (Fig.5). The amplitude of a modulation splash is proportional to $\sqrt{D \cdot N} \propto (D \cdot \Delta K / \delta K)$, i.e. it is proportional to the square root of the ratio of spectrum width to the spectral width of a single mode. The value of imperfection level *D*, the value of spectrum width $\Delta K$ (or the number of modes *N*) and the value of the amplitude of a modulation splash have the greater, if the level of energy absorption decreases.

During the instability evolution the spectrum width $\Delta K$ and the amplitude of a forced interference modulation splash (21) decrease.

Let discuss now the behavior of modulated wave in the neighborhood of the modulation splash. Spatial interval, where the amplitude of modulation is large, is $1/\Delta K \propto 1/K_{N/2} \propto 10/k_0$ if $k_0 \propto 10K_{N/2}$, i.e. that interval is wider then a wave-length of the main mode. In the domain of modulation splash there are a few wave-length of the main mode, if $k_0 \propto 20K_{N/2}$. When the system comes to continuous spectrum of instability ( $\delta K \to 0, N \to \infty$ ) a forced interference modulation splash will be infrequent one, but with the significant amplitude. Thus the phenomena of forced interference of instability spectrum modes causes an appearance of anomalous splash of the fine structure of perturbation amplitude at early stage of nonlinear rate of instability.

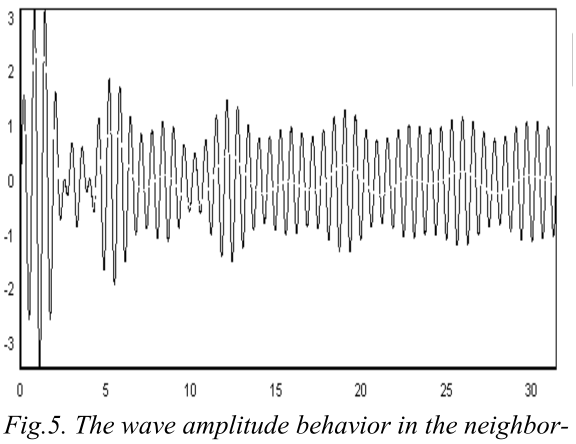



*Fig.5. The wave amplitude behavior in the neighborhood of modulation splash under following conditions: D = 0.7, a variation interval of x is equal to 31.4, a wave vector of the main mode* $k_0 = 10$, *a wave vector of the central mode of modulation spectrum* $K_{N/2} = 1$, *a spectrum width of modulation* $\Delta K$ *= 0,8. The white line in the picture corresponds to the envelope of modulation spectrum or, in other words, to the second item in (17)*

Frequency of splash appearance is determined by difference of phase velocity of modes. These modes form the wave modulation. The amplitude of splash depends on the number of modes or on phase spectral concentration in the instability spectrum (see Fig.5).

From the equations (16)-(27) one finds that an amplitude of the main mode changes from the initial value $u_0(t = 0) = 1$ to $\sqrt{\delta}$. At the same time the modes of unstable spectrum at first increase, then after the sign reversal of second term of equation (19) (see also (26)) decrease their's amplitudes. Finally only two modes remain, where the wavenumbers are near $k_0 + K_{n*}$, $k_0 - K_{n*}$ (where $K_{n*} \approx \sqrt{\delta}$ ) and amplitudes are equal to $u_{n*} \propto \sqrt{\delta (1 - \delta)/2}$.

In nonlinear systems the phase locking causes the regulation and stabilization of a phase position in well-defined reference frame (at the expense of attractors appearance and static stabilization). In case of the quasi-linear operation the phase locking means somewhat different. This is so indeed, only relative phase velocities are given by the pump, which determines in that way the phase dynamics of unstable modes (that is well-ordered dynamics, without statical stabilization).

## 4. THE FINE STRUCTURE OF A LASER PULSE

We consider this phenomena using, the operating regime of a laser. In one-dimentional case, the nonlinear set of equations, describing the excitation of laser radiation slightly above the generation threshold, can be written in the form

$$de_n / dt + \kappa e_n - i\Delta'_n e_n = -ip_n,$$
$$dp_n / dt + \Gamma p_n = i\mu e_n,$$
$$d\mu / dt = \Gamma_0 (1 - \mu) - \mathrm{Im} \sum_n e_n p_n^*, \qquad (32)$$

where $e_n, p_n$ – the dimensionless electric field and polarization, $\mu$ – relative dimensionless inverse population rate in two-state active medium, $\Gamma_0, \Gamma, \kappa$ – inverse time of the relaxation of the inverse population, line width, rate of losses in the resonator chamber, normalized to the maximum growth rate $(\mathrm{Im}\omega)_{MAX}$ in the absence of any losses ( $\kappa = 0$ ). Taking account of the losses, the maximum value of the growth rate of an instability exciting radiation electromagnetic waves correspond to the detuning value ( $\Delta_n = 0$ ) is equal to

$$\mathrm{Im}\omega_{\max} / \mathrm{Im}\omega_0 = \frac{1}{2}\{[4\mu + (\kappa - \Gamma)^2]^{1/2} - (\kappa + \Gamma)\}. \quad (33)$$

We also neglect below any spatial perturbations of the population inversion $1 - \mu << \mu$ .

On condition slightly above the threshold $\mathrm{Im}\omega << \Gamma, \kappa$ the equations are changing

$$dA_n / d\tau = [1 - \Lambda_n^2 - \sum_m A_m^2] A_n, \qquad (34)$$

$$d\alpha_n / d\tau = -\Lambda_n \delta^{-1} [1 - \delta^2 \Lambda_n^2], \qquad (35)$$

where $E_n = A_n \exp\{\alpha_n \tau\}$, $\tau = -t(\kappa + \Gamma)(\kappa\Gamma - 1)^{-1}$, $|e_n|^2 (\kappa / \Gamma_0)(\kappa + \Gamma)^{-1} = |E_n|^2$, $\delta^2 = (1 - \kappa\Gamma)(\Gamma^2 - 1)^{-1}(\kappa + \Gamma)^{-1}$, $\Lambda_n^2 = \Delta'^2_n (\Gamma^2 + 1)(\kappa + \Gamma)^{-1}(1 - \kappa\Gamma)^{-1}$.

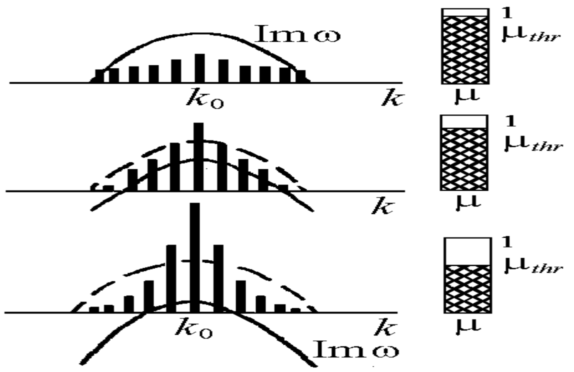



*Fig.6. Model of the mode competition for laser pulse formation*

In environment of slow amplitude change inthe spectrum of instability many modes (Fig.6) with comparable intensity remain. There is more than enough time for the phases to form quasiperiodical fine structure of a laser pulse is show in Fig.7. The phase velocity of each mode is practically proportional detune value $\Delta_n$.

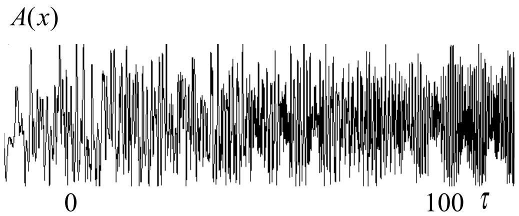



*Fig.7. The amplitude pulse development at change $\tau$ from 0 to 100, number of modes is N=50, $\delta = 0{,}35$*

The paired modes with $\pm|n|$support periodical modulation of radiation with period $\propto 2\pi/\Delta_n$. The superposition of such modulations forms the fine structure of the laser pulse.

At a great time the modes with large detuning value $\Delta_n$ insensibly decrease and a single-mode generation is realized [3].

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## ЭФФЕКТ ИНДУЦИРОВАННОЙ ИНТЕРФЕРЕНЦИИ И ФОРМИРОВАНИЕ ПРОСТРАНСТВЕННО ВОЗМУЩЕННОЙ ТОНКОЙ СТРУКТУРЫ В НЕРАВНОВЕСНОЙ ОТКРЫТОЙ СИСТЕМЕ

**В.М. Куклин**

Показано, что моды нестабильного спектра неустойчивости вблизи порога способны сформировать долго живущую тонкую структуру и аномальные интерференционные всплески, индуцированные накачкой.

## ЕФЕКТ ІНДУКОВАНОЇ ІНТЕРФЕРЕНЦІЇ ТА ФОРМУВАННЯ ПРОСТОРОВО ЗБУРЕНОЇ ТОНКОЇ СТРУКТУРИ У НЕРІВНОВАЖНІЙ ВІДКРИТІЙ СИСТЕМІ

**В.М. Куклін**

Показано, що моди нестабільного спектру нестійкості поблизу порогу здібні сформувати тривало живучу тонку структуру та аномальні інтерференційні сплески, індуковані накачкою.