(6), the effects in questions come into play at an incident-pulse duration $\tau_0 \lesssim 3\times10^{-12}$ sec.

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1) Here and throughout we have in mind the case of greatest practical interest, when the width of the spectrum of the incident radiation is governed by the time variation of the envelope f(t). This is easy to establish, e.g., by comparing the width of the incident-radiation spectrum with the longitudinal dimension of the relief in the two-photon luminescence track of two identical opposing beams (not focused by a zone plate).

2) To be able to conveniently increase the dimensions of the focal region itself, one can use beams that have been previously defocused (focused) with an ordinary lens and then focused (defocused) with a zone plate.

POSSIBILITY OF DYNAMIC DEFORMATION OF SPHERICAL NUCLEI

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It is demonstrated with a simple model that as the angular momentum of the nucleus is increased, a dynamic instability of the spherical state can set in, and is due to the competition between the pairing and the forces of quadrupole-deformation.

In connection with the observation of regular quasirotational bands in spherical even-even nuclei [1], the question of the change of the internal structure of the nucleus with increasing angular momentum I becomes timely. To attain $I \neq 0$ it is necessary to break the spherical pairs and this can lead to a "phase transition" even if the static deformation in the ground state (I = 0) is energywise not favored. This may be, in particular, the cause of the singularities in the spectra of ^{186}Hg [2] and $^{100,102}Pd$ ("V-event" [3]).

We consider a simple model [4] in which N outer nucleus fill a degenerate shell that includes $2\Omega << 1$ states and interact via pairing and quadrupole forces

$$H = H_P + H_Q = -\frac{G}{2} A^+A - \frac{\kappa}{2} \sum_\mu Q_\mu^+ Q_\mu . \qquad (1)$$

Here $A = \sum_\nu a_\nu a_{\tilde\nu}$ is the Cooper-pair operator, Q_μ is the total quadrupole moment, G and κ are coupling constants. The pairing H_P is diagonalized [5] by changing over to the pseudospin S

$$A = 2(S_x - iS_y), \qquad A^+ = 2(S_x + iS_y), \qquad N = \Omega + 2S_z ,$$
$$H_P = \text{const} - 2GS(S+1), \qquad (2)$$

where S varies from $\Omega/2$ (seniority $v = \Omega - 2S = 0$) to $N - \Omega/2$, when $v = v_{max} = N$ or $(2\Omega - N)$. The minimum of H_P corresponds to $v = 0$, and the first excited state has $v = 0$ and is separated by a gap $2\Delta = 2G\Omega$. At the same time, neglecting the higher multipoles, H_Q yields a system of rotational bands [4]

$$H_Q \approx -\frac{\kappa}{2} q^2 C + \frac{\kappa}{2} q^2 b\, \mathbf{I}^2 , \qquad (3)$$

where q is the reduced matrix element of the single-particle quadrupole moment, $b = (6/5)\,[\Omega(2\Omega - 1)(2\Omega + 1)]^{-1}$, and C is the Casmir operator of the SU(3) group. In the band including levels with even angular momenta from 0 to I we have $C = (4/3)b\bar{I}(\bar{I} + 3)$ [6].

In the absence of pairing, static deformation is favored. In the ground band, C is maximal and the limiting angular momentum is equal to

$$\bar{I} = \bar{I}_{max}(N) = \Omega N\left(1 - \frac{N}{2\Omega}\right). \qquad (4)$$

For excited bands we have $\bar{I} < \bar{I}_{max}(N)$, and far from saturation $(I/\bar{I} << 1)$ the rotation is adiabatic, i.e., the ratio of the intervals inside the band to the distance between the bands with equal C is small, $\sim I/\bar{I}$. For the quadrupole matrix elements, the Alaga rules are satisfied, and the intrinsic angular momentum is equal to $Q_0 = \sqrt{4b/3}q\bar{I}$.

In the presence of pairing, the number of particles (holes) that become involved in the rotation is $\leq v$; to maximize C, this number must be set equal to v. The $\bar{I} = \bar{I}_{max}(v)$ and the system energy takes the form

$$E(x, k) = \text{const} + x(1 - \frac{x}{2}) \left[\gamma - x\left(1 - \frac{x}{2}\right)\right] + \frac{3}{4}k^2 \equiv$$
$$\equiv E(0, 0) + \Phi(x) + \frac{3}{4}k^2, \tag{5}$$

where we have discarded the terms $\sim \Omega^{-1}$ and put $E = \langle H\rangle/\Omega F$, $F = (2/3)\kappa q^2 b\Omega^3 \simeq \kappa q^2/5$, $\gamma = \Delta/F$, $x = v/\Omega$, and $k = \sqrt{I(I+1)}/\Omega^2 \leq \bar{k} \simeq \bar{I}/\Omega^2 = x(1 - x/2)$.

It suffices to consider half the shell, $0 \leq x \leq N/\Omega \leq 1$. In the case of strong pairing $(\gamma > 1/2)$, the absolute minimum of $\phi(x)$ for all N corresponds to $x = 0$ (spherical symmetry). If $\gamma < 1/2$, then at $N/\Omega = 1 - \sqrt{1 - 2\gamma}$ there takes place the phase transition $(x = 0) \rightarrow (x = N/\Omega)$, with onset of static deformation $(k = 0)$. The transition point agrees with the one obtained in [7] from the condition that the frequency of the quadrupole oscillations vanish. It is easy to see that even in the spherical region a nonlinear angular momentum can lead to dynamic deformation, for to obtain $k \neq 0$ it is necessary to break the pairs, namely, $x \geq x(k) = 1 = \sqrt{1 - 2k}$. In the case of small occupation, $N/\Omega < 1 - \sqrt{1 - \gamma}$, we have $\Phi(x)$ increasing with x, and the minimum energy for a given k is reached at $x = x(k)$. Then (5) yields a nearly-equidistant spectrum

$$E(k) \equiv E(x(k), k) = \gamma k - \frac{1}{4}k^2 \tag{6}$$

On the other hand, if $N/\Omega > 1 - \sqrt{1 - \gamma}$, then there exists a region of x where $\phi(x)$ takes on identical values at two different values of the seniority

$$x_{\pm} = 1 - \sqrt{1 - \gamma \mp \zeta}, \quad \phi(x_+) = \phi(x_-) = \frac{\gamma^2 - \zeta^2}{4}. \tag{7}$$

Let $N/\Omega = x_+$, and we increase the angular momentum: $0 < k < \bar{k} = (\gamma + \zeta)/2$. So long as $x(k) < x_-$, it is convenient to choose $x = x(k)$, and the spectrum is given by (6). At the point $k = k_c = (\gamma - \zeta)/2$, where $x(k_c) = x_-$, degeneracy of the old band and of the "deformed" state with $x = x_+$ takes place. With further increase of the angular momentum $(k > k_c)$, the lowest band will be the one with fixed maximal $x = N/\Omega$ and with rotational energy

$$E(k) = E(k_c) + \frac{3}{4}(k^2 - k_c^2). \tag{8}$$

The band (6) with $x = x(k)$ is shifted upward by $\Delta E(k) = (k - k_c)(\gamma - k - k_c) > 0$, and the ratio of the slopes of the energies of the bands near the base of the V-event is equal to $a = (2\gamma - k_c)/3k_c$.

Thus, in spherical nuclei with $N/\Omega > 1 - \sqrt{1 - \gamma}$, at a sufficiently large angular momentum, dynamic deformation sets in. Although the considered model is only qualitative in character, it does yield reasonable estimates of the principal quantities. Thus, for Pd isotopes, we get $\gamma \simeq 2/3$ from the absence of static deformation in the neutron shell (the levels $d_{5/2}$, $g_{7/2}$) and from the absence of branching in ^{98}Pd; then $k_c \simeq 1/4$, i.e., $I_c \simeq 12$ (actually $I_c = 8$), the slope ratio is $a \simeq 1.45$ (experiment yields $a = 1.4$ for ^{102}Pd and $a = 1.25$ for ^{100}Pd). What is characteristic of this mechanism is the approximate satisfaction of the Alaga rules in a band with dynamic deformation, whereas along the quasirotational band $(I \| Q \| I + 2)^2 \simeq q^2 b = \text{const}$, $(I \| Q \| I)^2 \simeq (1/6)q^2 bI$, $(I >> 1)$. To develop a microscopic theory it is necessary to include the n-p interaction, which facilitates the onset of the effect.

[1] S. Scharff-Goldhaber and A. S. Goldhaber, Phys. Rev. Lett. 24, 1349 (1970).
[2] D. Proetel, R. M. Diamond, et al., Proc. Int. Conf. Nucl. Phys. 1, 319, Munich, 1973.

[3] S. Scharff-Goldhaber, M. McKeown, et al., Phys. Lett. 44B, 416 (1973).
[4] V. G. Zelevinskii, Proc. 7-th School of Leningrad Inst. of Nuc. Phys., 1972, p. 139.
[5] P. W. Anderson, Phys. Rev. 112, 1900 (1958).
[6] J. P. Elliott, Proc. Roy. Soc. A245, 128, 562 (1958).
[7] S. T. Belyaev, Kgl. Danske. Vid. Selsk. Mat.-Fys. Medd. 31, No. 11 (1959).

DYNAMIC NEGATIVE DIFFERENTIAL CONDUCTIVITY (NDC) IN HOMOGENEOUS AND ELECTRICALLY-STABLE SEMICONDUCTORS

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A homogeneous semiconductor can have a negative differential conductivity (NDC) at a nonzero frequency, and nevertheless remain stable against arbitrary fluctuations.

The existence of NDC in inhomogeneous semiconductors that are stable against electric fluctuations is a well known and long established fact. Examples are tunnel diodes, impact avalanche and transit time diodes, and others. It is also known that in homogeneous semiconductors the presence of static NDC leads to a growth of sufficiently long-wave fluctuations and, in final analysis, to the breakdown of the sample into domains. We wish to call attention to the fact that dynamic DNC can occur in homogeneous semiconductors in a certain frequency band ω in the absence of static NDC owing to the dispersion of the differential conductivity $\sigma_d(\omega)$, i.e., we can have in the frequency interval $0 < \omega_1 \leq \omega \leq \omega_2 < \infty$ at $\sigma_d(0) > 0$

$$\mathrm{Re}\,\sigma_d(\omega) < 0, \tag{1}$$

and in spite of (1), the semiconductor remains stable against fluctuations at all frequencies and at all wavelengths.

This possibility was corroborated by us in detail, using as an example a homogeneous monopolar semiconductor having traps of two types, 1 and 2, and having capture coefficients $C_{1,2}(E)$ that depend on the electric field intensity and having ejection probabilities $g_{1,2}(E)$. We solved the standard linearized system of equations of the recombination kinetics, as well as the Poisson and continuity equations, and calculated the differential conductivity $\sigma_d(\omega, K) = \delta j/\delta E$ with account taken of the temporal and spatial dispersion (δj and δE are the variations of the current density j and of the field E, respectively, at the frequency ω and wave number K). In the simplest case of ohmic contacts on the boundaries X = 0 and X = L, an alternating electric signal of frequency ω applied to the sample excites in the interior of the sample only homogeneous oscillations with wave number K = 0. Then the impedance is $Z(\omega) = L\sigma_d^{-1}(\omega, K = 0) \equiv L\sigma_d^{-1}(\omega)$, and the condition (1) is equivalent to $\mathrm{Re}Z(\omega) < 0$. In other words, the current and the voltage of frequency ω are shifted in phase by an angle larger than $\pi/2$, i.e., a power gain is obtained on the average over the period of the oscillations. When such a sample is connected to a tank circuit tuned to the frequency ω, self-excitation of oscillations can take place. Of course, to realize this possibility the semiconductor must remain stable against fluctuations and, for example, not break up into domains.

To check on the stability of the fluctuations, we solved the dispersion equation

$$\sigma_d(\omega, K) = 0 \tag{2}$$

with respect to ω for arbitrary real values of K. We sought semiconductor parameters such that (a) the condition (1) could be satisfied at any real frequency ω and (b) the imaginary part $\mathrm{Im}\omega$ of the complex roots of Eq. (2), for any real K, had a sign corresponding to damping of the fluctuations with time. It is convenient to represent the results of such an analysis in the plane of the variables ξ and η (see the figure), where