$\ll c/\omega$, which is the case with most present-day experiments, the results can still be applied, with an appropriate scaling, provided that Ω_0 (essentially the mirror ratio) remains fixed. For example, if we take a set of parameters typical of the Phoenix II experiment[6]: $B(0)=12.5$ kG, $L_E=7$ cm, mirror ratio $R=1+\alpha=1.357$, $\Omega_0=1/1.1R$, the scaling is $\beta=24.1$. The computed result, $v_{\parallel\max}=0.02$ with $g_0=0.0130$, then implies that 0.33-keV protons would be confined by an electric field of 3 kV cm^{-1}. Thus experimentally realizable fields could lead to the trapping of slow ions, which in turn could lead to the build-up of fast ions. Furthermore, since after scaling the unit of v is $L_E\omega$ and that of E is $L_E\omega^2$, for $L_E=14$ cm and $B(0)=16$ kG, protons of 5 keV could be confined by an electric field of 23 kV cm^{-1}.

In extrapolating the results reported here towards a thermonuclear reactor, two questions arise. Firstly, one might ask whether this method of confinement is very sensitive to collisions in the mirror region. A partial answer can be obtained by regarding a collision as equivalent to a reinjection of the particle at $z\neq 0$ with new values of $v_\parallel$ and v_L. To emphasize that a particle can easily remain confined after such an event, we have indicated in Fig. 3(a) the adiabatic boundary for particles injected at $z=0.57$. Secondly, it may be asked how far the above discussion requires modification to take into account the influence of the plasma on the electric field profile which would exist inside it. As was shown in Ref. 5, the self-consistent profile can be calculated if the adiabatic invariants are assumed to be conserved. Such profiles are more complicated than the linear profile adopted here, and the adiabaticity of particles in such profiles is currently under investigation.

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NEW ECHO PHENOMENA IN SUPERCONDUCTORS AND IN NORMAL METALS

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Echo phenomena were observed in normal and superconducting powdered metals. They are believed to be related to magnetoacoustic modes.

In a recent Letter[1] Goldberg, Ehrenfreund, and Weger reported the observation of echoes in superconducting powders. These echoes are somewhat similar to spin echoes[2] and to cyclotron echoes observed in plasmas.[3] The authors suggest this phenomenon may be connected with the motion of pinned fluxoids. We had made similar observations[4] in powdered lead alloys below their critical field H_{c2}. We also observed[4] the same type of echoes in nonsuperconducting pure metals (Pb, Cu, In, Sn) when the particle size of the powders was larger than the skin depth.

The experimental results of Goldberg, Ehrenfreund, and Weger agree with ours in practically all aspects. In particular, the decay times of the echo envelopes are of the same order of magnitude for all the samples. The only discrepancy is connected with the field dependence of the echo amplitude. We found an H^2 law for pure lead ($H\gg H_c$). For superconducting lead alloys the behavior is illustrated in Fig. 1. The echo disappears quite abruptly at the phase transition

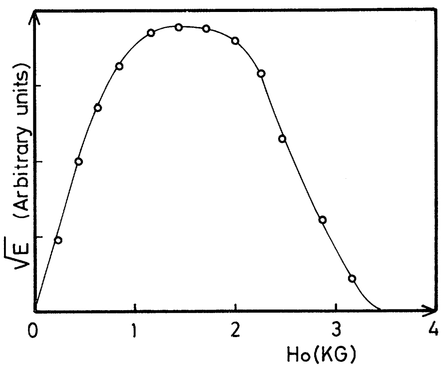

FIG. 1. Square root of the echo amplitude versus magnetic field in a Pb:Hg (5%) sample. The rf frequency is fixed, 5 Mc/sec. The measurements were taken at 4.2°K. The magnetic field covers a range extending below and above $H_{c2} \simeq 2.2$ kG.

to the normal state.

We have also obtained the following results, previously unpublished:

(1) When the powders are immersed in a liquid which solidifies at helium temperature, the echoes disappear. We used alcohol, glycerine, and solid argon.

(2) When the metallic particles are mixed with an insulating powder in order to avoid electrical contact between particles, the echo is unaffected.

(3) No echo was observed in 40-μ thick lead foils for all orientations of dc and rf magnetic fields.

(4) The size of the metallic particles is quite critical. The echo disappears for average diameters bigger than 100 μ or smaller than 10 μ.

All this suggests that the observed echo phenomena are not basically different in superconductors and in normal pure metals. We still believe[4] that magnetoacoustic modes[5] are at the origin of the echoes. This is supported by the fact that magnetomechanical transient signals (ringing) were also present, with an amplitude dependence similar to that of the echoes. Finally one should notice that similar echo phenomena were previously observed in ferromagnetic materials, and were first attributed to domain-wall motions. However a recent report concludes that these are magnetostrictively excited acoustic resonances.[6]

It is quite clear that the appearance of echoes implies some nonlinear process.[7] The origin of the nonlinearity may be different in superconductors, normal metals, and ferromagnets. A detailed picture would be required to allow a quantitative study of the measured decay times. The complex geometry of the powdered samples may, however, limit the feasibility of such attempts.

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