ducing high excitations.

The magnitude of the cross sections anticipated is large. Detailed calculations are in progress, but we expect the differential fission cross section for scattering of the projectile into the backward direction to be the Coulomb differential cross section times a factor which involves the initial orientation of the target (and varies from 0 at threshold to perhaps the order of $\frac{1}{10}$ or 1/100). The Coulomb cross section is $(d/4)^2$. We are in the range ~1 mb/sr. (This assumes adiabaticity.)

Specifically, we propose experiments which involve (1) even-even targets such as Th^{232} and U^{238}; (2) the heaviest projectiles available at variable energies exceeding estimate (4); (3) coincidence of fission with the scattering of the projectile, particularly into the backward direction; (4) observation of the fission fragment angular distribution, which we expect to peak at 90° in the center-of-mass frame; (5) comparison of various fission characteristics, such as mass distribution, kinetic energy, etc., with other methods of inducing the reaction; and (6) measurement of projectile energy loss. Not all of these items are essential to a useful experiment.

We have learned[6] subsequent to the preparation of this note that an experiment on Coulomb fission (Ar^{40} on U^{238}) has been undertaken by T. Sikkeland at the Lawrence Radiation Laboratory, following a suggestion by A. Winther, who has considered some of these questions. Reference to Fig. 1 shows that a larger mass projectile would be desirable.

We wish to acknowledge stimulating discussions with Dr. J. J. Griffin, Dr. J. R. Huizenga, Dr. H. W. Schmitt, and Dr. P. H. Stelson.

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[1]J. R. Huizenga, private communication. See also I. Halpern, Ann. Rev. Nucl. Sci. 9, 245 (1959).

[2]This method was first used by R. Chaudhry, R. Vandenbosch, and J. R. Huizenga, Phys. Rev. 126, 220 (1962); cf. also "Deformation of the Transition State Nucleus in Energetic Fission," R. F. Reising, G. L. Bate, and J. R. Huizenga, Argonne National Laboratory (to be published).

[3]The fissile nuclei have static prolate deformations and are softer to further β deformation than to γ deformation. The stiffness to γ deformation undoubtedly increases as the nucleus deforms further. The shape that a nucleus assumes as it moves to fission would be that of a flattened cigar (γ small but not equal to zero). A quantitative statement of the flattening effect is model dependent, but we anticipate it to be small for the considerations here.

[4]E. K. Hyde, I. Perlman, and G. T. Seaborg, The Nuclear Properties of the Heavy Elements (Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1964), Vol. I, p. 148.

[5]Cf. L. C. Biedenharn and P. J. Brussaard, Coulomb Excitation (Clarendon Press, Oxford, England, 1965). In an unpublished preprint, 1957, L. C. Biedenharn and R. M. Thaler specifically considered Coulomb excitation leading to fission.

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HIGH-ORDER FLUCTUATIONS IN A SINGLE-MODE LASER FIELD*

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There is a great deal of theoretical[1-4] and experimental[5-7] investigation about the statistical nature of a single-mode laser field, and the most-used model has been that of an amplitude-stabilized sine wave with a slowly varying random phase $E_0\cos[\omega t+\varphi(t)]$ plus a stationary noise field $e_n(t)$ whose magnitude is much less than E_0. We give in this Letter experimental evidence of the accuracy of this model, pushing the field correlation measurements two orders further than the ordinary intensity fluctuations (or Hanbury Brown–Twiss type) experiments until now performed.[5-8]

First, we shall make some remarks on an experiment where we have superposed an amplitude-stable single-mode laser and a Gaussian field and studied the photon correlations in the superposed field. Then we shall apply

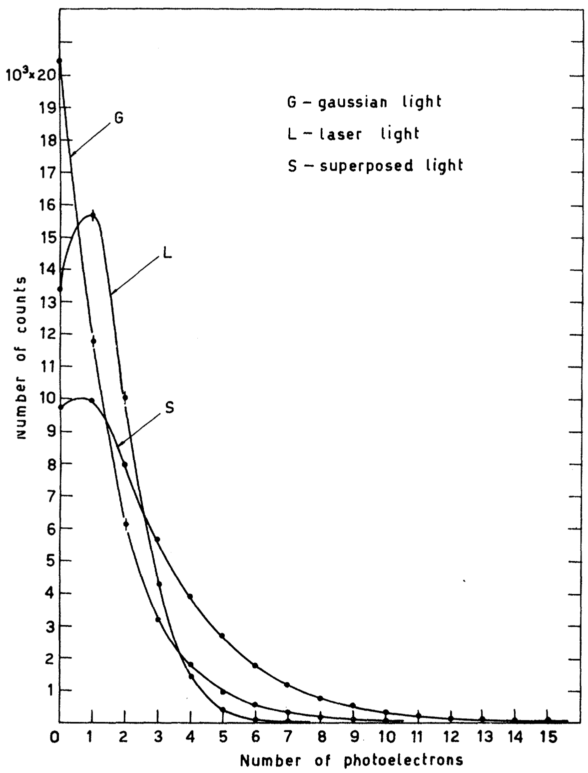

FIG. 1. Photocount distributions for Gaussian, laser, and superposed field. Measuring time of a single sample: 10 μsec. Coherence time of the Gaussian field: 40 μsec.

similar considerations to a laser near threshold, separating a coherent and a Gaussian field contribution to the first- and second-order correlation functions, and verifying the correctness of this procedure on the third- and fourth-order correlations.

In the first case we have superposed two independent fields, one fully coherent and the second Gaussian, matching carefully the wave fronts and making observations within a coherence area and a coherence time of the resultant field, and have reported the statistical distribution of photon counts using a method described elsewhere.[9] The Gaussian source has been obtained by random superposition of a great number of coherent fields.[9] Both Gaussian and coherent distributions are plotted in Fig. 1 together with the superposed distribution, and their moments are reported in Table I. In looking at the second moments, we see that these results verify a theoretical expectation pointed out by Morawitz[10] in a recent paper. Obviously, the plotted distributions contain much more information than a simple intensity correlation, and to illustrate this, the third moment of the superposed field is also listed in Table I together with the expected theoretical value.

Calculations of Table I stem from the following theoretical considerations,[11] that we report briefly. If we call γ the amplitude of the coherent field and $\langle n\rangle$ the average occupation number of the Gaussian field, the P function[1] for the superposed state is given by

$$P(\alpha)=\frac{1}{\pi\langle n\rangle}\exp\left(-\frac{|\alpha-\gamma|^2}{\langle n\rangle}\right), \tag{1}$$

and the corresponding generating function of the photoelectron count distribution is given by

$$Q(\lambda)=\frac{1}{1+\lambda\langle n\rangle}\exp\left(-\frac{\lambda|\gamma|^2}{1+\lambda\langle n\rangle}\right), \tag{2}$$

where we have assumed that measurements are performed within a coherence time and area (first-order correlation functions independent of time). This relation has the same form as the generating function for the Laguerre

Table I. Moments and associated errors of the statistical distributions of Fig. 1.[a]

	$M_1=\langle C\rangle$		$M_2'=\langle C\rangle^2-\langle C\rangle^2$		$M_3=\langle C^3\rangle$		Expected experimental errors[c]		
	Expt.	Theory[b]	Expt.	Theory[b]	Expt.	Theory[b]	M_1 (%)	M_2 (%)	M_3 (%)
L	$\|\gamma\|^2=1286$	···	1.301	1.286	8.435	8.375	0.43	1.58	1.1
G	$\langle n\rangle=1.202$	···	2.633	2.647	···	···	0.63	2.55	···
S	2.524	2.488	6.846	7.025	92.32	98.56	1.1	3.4	10.6

[a] M_1 and M_3 referred to the zero line; M_2' referred to the center, in order to have the variance.
[b] Theoretical values are calculated using, respectively, a Poisson distribution for L; a Bose distribution for G; and the formulas for the superposed field for S, that is $M_1=|\gamma|^2+\langle n\rangle$, $M_2'=|\gamma|^2+\langle n\rangle(1+\langle n\rangle)+2|\gamma|^2\langle n\rangle$, and so on.
[c] Calculated for $|\gamma|^2$ and $\langle n\rangle$, by taking into account the count numbers per channel as given by Fig. 1, and for the superposed distribution, through the relations between M_1, M_2, M_3, and $|\gamma|^2,\langle n\rangle$.

polynomials[12] L_n; therefore one easily calculates the factorial moments (denoting by C the number of counts) as follows:

$$\langle C(C-1)\cdots(C-n+1)\rangle = \langle n\rangle^n L_n(-|\gamma|^2/\langle n\rangle). \tag{3}$$

Relation (3) allows us to compare the experimental values of the moments $M_k = \langle C^k\rangle$ of the superposed field with the theoretical values given in terms of the mean numbers of counts $|\gamma|^2$, $\langle n\rangle$ of the component fields. Results are reported in Table I.

Now we go to the main problem of investigating the nature of the laser field. If this can be considered as made of a coherent contribution plus a Gaussian noise, then its P function is given by (1), provided the observation time is below the coherence time of the noise, which can be measured by standard frequency techniques.[5,6] Calling x and y the mean numbers of quanta pertaining separately to the coherent and chaotic field, respectively, one has the relations

$$x+y=M_1, \quad x^2+4xy+2y^2=M_2-M_1, \tag{4}$$

where M_1 and M_2 are the measured first and second moments of the photocount distribution.

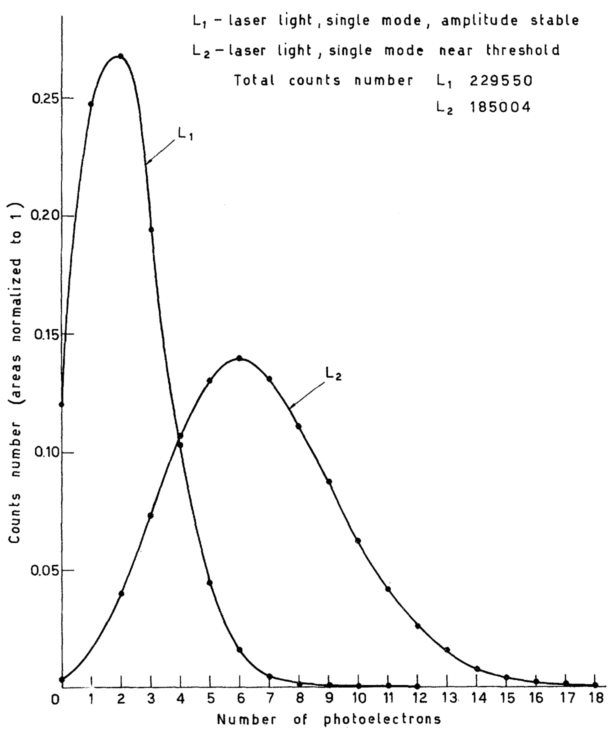

FIG. 2. Photocount distributions of two laser fields (referred to different average photon numbers). Measuring time of a single sample: 10 μsec.

Table II. Deviation of distributions L_1 and L_2 from Poisson.

	M_1	M_2' Expt.	M_2' Deviation from Poisson (%)
L_1	2.145	2.165	0.9
L_2	6.672	8.345	20

In Fig. 2 we have reported two distributions for a single-mode laser. The first, for the laser well above threshold, is a pure Poissonian to within the experimental errors; the second, for the laser near threshold, deviates from Poisson as reported in Table II. The observation time was 10 μsec, whereas the noise coherence time (reciprocal of the excess-noise frequency cutoff) was larger than 50 μsec. Relations (4) allow us to calculate the values $x=6.53$ and $y=0.14$ for the laser near threshold, and similar formulas for the next two factorial moments allow us to check the validity of our assumption. The accuracy is reported in Table III and appears to be very satisfactory; namely, deviations of 1.5 and 6%, for the third and fourth factorial moments, respectively, are within the experimental errors. Thus our results show that the description of a single-mode laser in terms of superposed Poissonian and Gaussian fields is accurate to very high order of field correlation.

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[1]R. J. Glauber, in Quantum Optics and Electronics; Lectures Delivered at Les Houches During the 1964

Table III. Third and fourth factorial moments of distribution L_2.

	$C(C-1)(C-2)$ Expt.	$C(C-1)(C-2)$ Theory	$C(C-1)(C-2)$ Deviation	$\langle C(C-1)(C-2)(C-3)\rangle$ Expt.	$\langle C(C-1)(C-2)(C-3)\rangle$ Theory	$\langle C(C-1)(C-2)(C-3)\rangle$ Deviation
L_2	329.6	334.5	1.5%	2404	2543	6%

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DETERMINATION OF THE BRANCHING RATIO FOR THE DECAY OF RHO MESONS INTO MUON PAIRS*

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An experiment on photoproduction of muon pairs from carbon has been performed at the Cambridge Electron Accelerator using a 5.2-BeV bremsstrahlung beam. The data, when compared to Bethe-Heitler theory, exhibit an enhancement of muon pairs having an invariant mass corresponding to that of the ρ meson. These muons are interpreted as arising from leptonic decay of the ρ meson. This previously unreported experiment is an improved version of an earlier experiment.[1,2] It has more than 40 times the data of the earlier work and has reduced errors due to detector geometry and electronics.

The experiment utilized thick iron filters to separate pions from muons. Figure 1 schematically shows the experimental arrangement. A muon-pair trigger was generated when two charged particles, one on each side of the γ beam, traversed 4 ft 3 in. of iron. When a trigger was generated, 160 hodoscope detectors were observed in coincidence. The hodoscope counters measured the angles and range of each member of the pair. Polar angles from 4.2° to 10.9° were detected in nine equal intervals. Azimuthal angular intervals of 42°, centered about 180°, were observed on each side of the γ beam in 6° intervals. The angle-defining counters were placed behind 3 ft of iron. Ranges were measured for each muon corre-