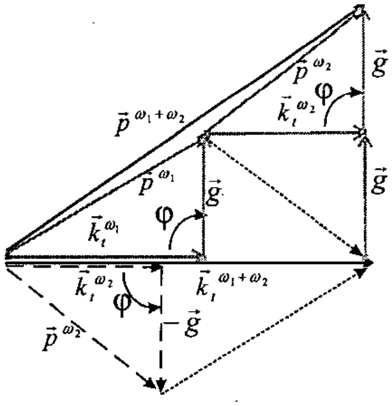
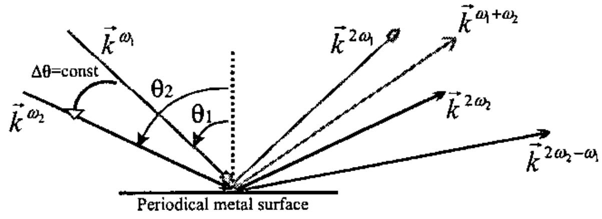
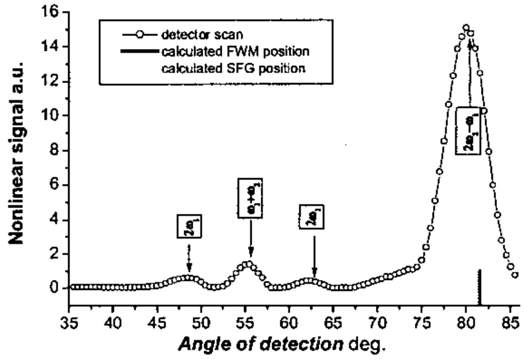


QFB4 **Fig. 1.** Wave vector arrangement on the grating surface.



QFB4 **Fig. 2.** Beams arrangement in the incidence plane.



QFB4 **Fig. 3.** Angular distribution of nonlinear signals.

optical signal is concerned with the electromagnetic field localization [ ]. In order to avoid the optical and thermal damage, the overage field should be weak enough we shell concentrate laser energy in space and time. In this work to make the spatial energy concentration and localization we are exciting surface electromagnetic waves (SEW) at the metal interface—surface plasmons if the phase matching conditions are fulfilled.[1] Femtosecond laser pulses are used for the achievement of high peak intensity due to the temporal pulse localization. The surface sensitivity can be enhanced with the three wave mixing process, because it is forbidden in the bulk.[2] For the spectroscopic applications tree wave mixing processes and four wave mixing (FWM) process are very important. In the recent paper we suggest a new method of nonlinear signal enhancement based on the interacting SEW. We demonstrate for the first time, the enhancement of sum frequency generation (SFG) and FWM process induced by interaction of several noncollinear SEW on the metallic grating surface.

We assume that the SEWs can be excited with a specific angle of incidence θ and angle of grating orientation φ: $\omega_{SEW,i} = \omega_i$, $\vec{p}_i = \vec{k}_{t,i} + n_i\vec{g}$, i = 1,2. Where *g* is reciprocal grating vector, $k_{t,i} = k_i \sin(\theta_i)$ is beam projection on a grating plane, *n* is diffraction order, *p*—is wave vector of SEW. When SEW of different frequencies are overlapped in space and time, sum frequency generation (SFG) and FWM ($\omega_{FWM} = 2\omega_1 - \omega_2$), occurs in definite direction. When φ is 90 degrees there are additional channels for nonlinear processes (double resonance) and signal is considerably higher.

For the experiment we used two beams of synchronized femtosecond pulses with wavelengths of 700 and 800 nm. We studied the influence of phase mismatching and spatial-temporal pulses overlapping on SFG and FWM processes. Second harmonic generation automatically takes place in our experimental scheme and it is the reference of SEW resonance quality.[2]

Propagation length of SEW proved to be comparable with focused laser beam waist, so noncollinear scheme does not has the disadvantage of smaller interaction area. For optimal conditions we obtained effective nonlinear susceptibilities $\chi_2 = 10^{-10}$ *CGSE*, $\chi_3 = 10^{-15}$ *CGSE*. FWM efficiency proved to be rather high. Note that χ_2/χ_3 ratio is smaller than for most of materials, that is because of different surface and bulk contributions to SFG and FWM processes.

In conclusion: the method of nonlinear surface optics is suggested and experimentally demonstrated. It is based on resonance excitation of several SEW witch interact on the surface, allowing us to enhance various nonlinear optical effects, sensitive to the surface properties.

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2. Y.R. Shen, *The principles of nonlinear optics*, John Willey and Sons, Inc. New York, 1984.

QFB5 9:15 am

Enhancement of Spontaneous Emission Rate in Nitrides by Resonant Surface Plasmon Coupling

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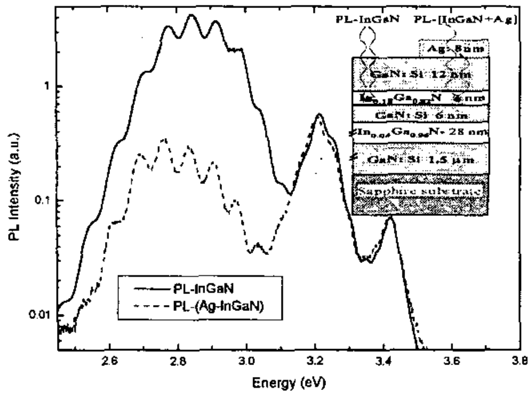
The spontaneous emission (SE) rate of a system may be modified by altering the photon density of states (P-DOS) and the local strength of the electromagnetic modes. The figure of merit or Purcell enhancement factor η can be estimated as the ratio of relaxation rates $\Gamma_{cavity}/\Gamma_{free\text{-}space}$. η of up to 6 have been observed from quantum well (QW) emitters in VCSEL structures, while η = 15 has been observed from quantum dots in a microdisk.[1] Photonic crystals have also been used to enhance the emission rate by as much as a factor of 3.5.[2] Such enhanced SE rates, permit lower threshold, higher modulation frequency lasers and efficient LEDs.

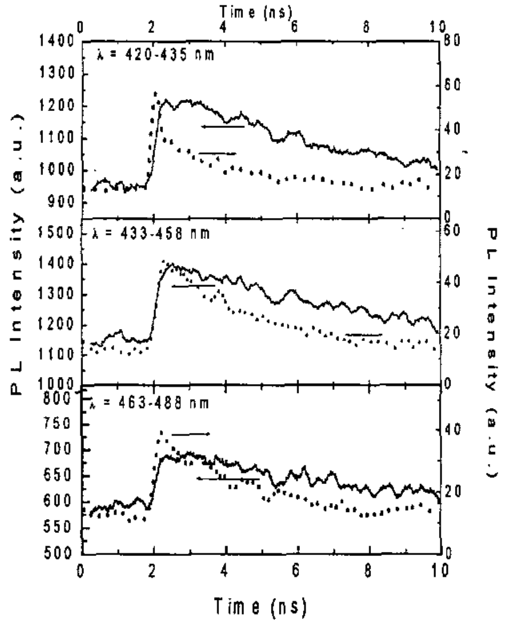
The P-DOS and the SE rate can also be modified when emitters are coupled to a surface plasmon (SP) of a metallic film.[3] A single QW (SQW) can experience strong quantum electrodynamical coupling to a SP mode if placed within the SP fringing field penetration depth (z). In this regime, an electron-hole pair in the SQW recombines and emits a photon into a SP mode instead into free space. The strongest enhancement occurs near the asymptotic limit of the SP branch, the SP "resonance" energy E_{sp}, where the SP DOS is very high. It is observed that silver-SP energy (3 eV) is modified (~2.85 eV) by a GaN dielectric surface as $\varepsilon'_{Ag}(\omega) + \varepsilon'_{GaN}(\omega) = 0$, where $\varepsilon'_{Ag}(\omega)$ and $\varepsilon'_{GaN}(\omega)$ are the real parts of dielectric constant, and the emission from a InGaN QW placed within z (≅40 nm) can be resonantly coupled to the SP modes (inset of Fig 1).[3]

The photoluminescence (PL) decay rate (Γ) from a photoexcited QW is related to the SE rate. The cw PL data in Figure 1 for the sample shown within the inset indicates the role of SQW emission into the SP modes as the normalized PL emission from the silvered SQW is more than an order of magnitude weaker than from the unsilvered SQW between 2.7–3.1 eV. A broad PL peak is observed from the unsilvered InGaN SQW at 2.75 eV, along with smaller peaks at 3.2 eV and 3.4 eV from the InGaN reference layer and the GaN buffer layer, respectively.

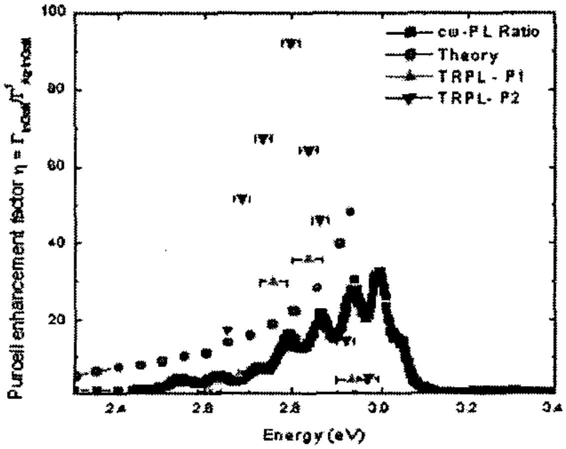
A more direct demonstration of resonant enhancement is observed from the time resolved PL (TRPL) measurements shown in Fig. 2. On the unsilvered side, the SQW exhibited a long single exponential decay whose decay constant τ_0 was slowest (τ_0 = 28 ns) at wavelengths near the peak



QFB5 **Fig. 1.** Sample structure and cw PL at 300 K measured by He-Cd laser at 325 nm.



QFB5 **Fig. 2.** Room temperature TRPL measurements using a Ti:Sapphire laser The pump excitation energy was 3.14 eV (395 nm), below the bandgap of the InGaN reference layer and GaN buffer layer so electron-hole pairs were generated only in the SQW. Emission wavelength dependence on the decay time for $\lambda_{ex} \sim 395$ (3.14 eV) with a wavelength window of 25 nm. Solid line indicates PL from InGaN side and dotted lines is the PL from the silvered side.



QFB5 **Fig. 3.** The Purcell enhancement factor, measured using cw PL (PL comparison) and TRPL (rate constant comparison).

PL emission (450 nm) and fastest (τ_0 = 4–5 ns) at the longest and shortest wavelengths measured (Fig. 2b). By contrast, the weaker PL intensity through the silver-coated surface exhibits a bi-exponential decay. The faster decay component is strongest near E_{sp} (2.85 eV), is evident within 200 meV of E_{sp}, and has a decay constant ($\tau_1 \sim 235$ ps). This indicates that τ_1 is a measure of the enhanced SE rate into the SP resonance at λ_{sp}, a process which occurs $\tau_0/\tau_1 = 60$ times faster (at 2.85 eV) than the decay into free space from the unsilvered side. In Fig. 3 the cw PL ratio demonstrates η with a maximum of 35 centered at 2.97 eV compared to the TRPL ratio, measured at two positions 'P_1' and 'P_2' with slightly differing silver layer thickness with $\eta = 36$ (at 2.83 eV) and 92 (at 2.79 eV), respectively.

The degree of enhancement increases with increasing film thickness and decreasing GaN cap layer thickness. Enhancement factors of almost 100 were indicated by dramatically accelerated TRPL decay at a frequency corresponding to the SP resonance.

References

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QFB6 **9:30 am**

Anderson Localization vs. Delocalization of Surface Plasmons in Nanosystems

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From a partial-differential eigenproblem, without use of dipole approximation, we show that the eigenmodes (surface plasmons) of disordered nanosystems (modeled as random planar composites) are not universally Anderson-localized, but can have properties of both localized and delocalized states simultaneously.[1] Their topology is determined by separate small-scale "hot spots" that are distributed and coherent over a length that may be comparable to the total size of the system. Coherence lengths and oscillator strengths vary by orders of magnitude from mode to mode at nearby frequencies. The existence of dark *vs.* luminous eigenmodes is established (the dark eigenmodes do not contribute to optical responses, and the luminous eigenmodes do) and attributed to the effect of charge- and parity-conservation laws. Possible applications are discussed. The theory is based on the spectral representation.[2]

The results for random planar nanostructured composites are illustrated in Fig. 1. They show that eigenmodes with a similar geometry of local field intensities (delocalized in this case) may be either luminous or dark [cf. (a) and (b)]. The distribution over the localization lengths L is very wide, from the minimum scale to the size of the entire system [Fig. 1(c)].