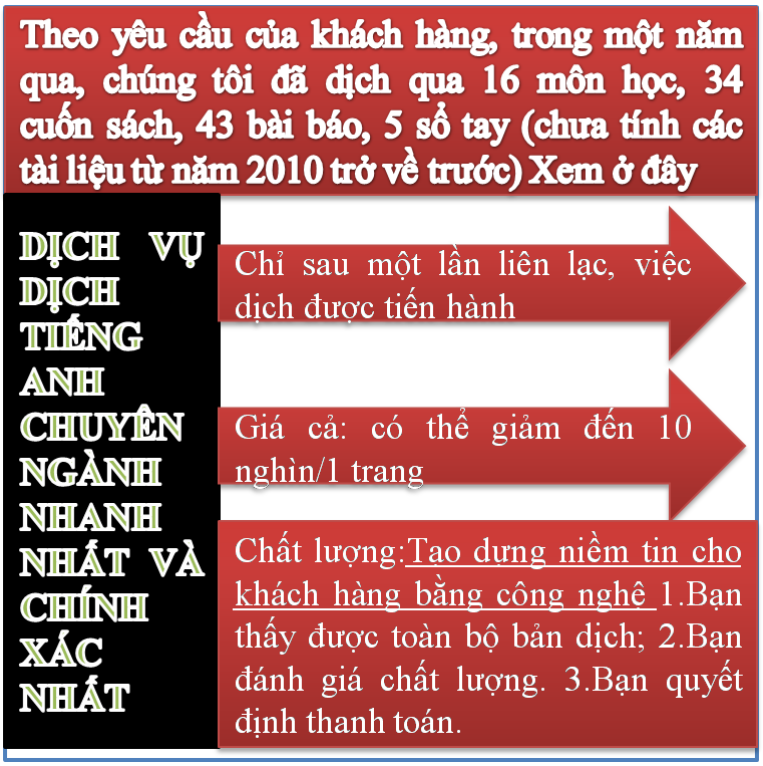

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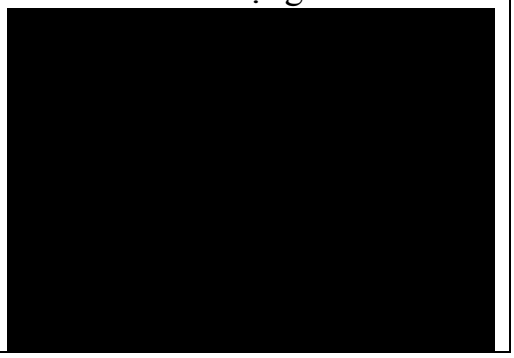
INDIVIDUAL DEDUCTION OF TWO ROUGHNESS PARAMETERS FOR QUANTUM WELLS FROM INTERSUBBAND ABSORPTION PEAK DATA	RÚT RA RIÊNG LẺ HAI THAM SỐ ĐỘ NHÁM CỦA CÁC GIẾNG LƯỢNG TỬ TỪ DỮ LIỆU PEAK HẤP THỤ GIỮA CÁC VÙNG CON check
Abstract. For roughness-dominated intersubband absorption in quantum wells (QWs), the optical characteristics depend on roughness parameters of the heterointerface (roughness amplitude and correlation length). Following the earlier belief in the literature, a single-valued estimation of them from, measurement of these characteristics is impossible. On the contrary, in our report we present an attempt at providing a possibility for single-valued deduction of the roughness parameters from optical data. For this purpose, we introduce the lineshape characteristics that are independent of roughness amplitude, so being a function of correlation length only. As a typical example, we examine the ratio between two different absorption-peak heights. Thus, we may propose an efficient method for individual estimation of the roughness parameters from optical data. Instead of the normal simultaneous fitting of both	Tóm tắt. Đối với trường hợp hấp thụ giữa các vùng trong giếng lượng tử (các QW) chủ yếu do độ nhám, đặc tính quang học phụ thuộc vào các tham số nhám của bề mặt phân cách không đồng nhất (biên độ nhám và chiều dài tương quan). Theo quan điểm trước đây trong các tài liệu, ước tính đơn trị chúng từ phép đo những đặc tính này là không thể. Ngược lại, trong nghiên cứu này, chúng tôi trình bày về khả năng rút ra đơn trị các tham số độ nhám từ dữ liệu quang học. Với mục đích như thế, chúng tôi trình bày các đặc tính hình dạng vạch phổ không phụ thuộc vào biên độ nhám, vì thế chúng chỉ phụ thuộc vào chiều dài tương quan. Như một ví dụ điển hình, chúng tôi sẽ thử rút ra tỷ số giữa hai độ cao peak hấp thụ khác nhau. Vì thế, chúng tôi cho rằng đây là phương pháp hữu dụng để ước tính riêng biệt các tham số độ nhám từ dữ liệu quang học. Thay vì khớp đồng thời cả hai tham số với hàm phụ thuộc chiều cao peak hấp thụ (APH) ở nhiều điểm thực nghiệm, chúng tôi thực hiện khớp hai bước ở

parameters to the functional dependence of the absorption-peak height (APH) at many experimental points, we perform a two-step fitting at one point.	một điểm.
I.INTRODUCTION Roughness-related scatterings are usually key scattering mechanisms in heterostructures (HSs), especially, thin quantum wells. These determine a great deal of their various properties, viz., lateral transport [1], intersubband optical transition [2], and excitonic lineshape [3]. Roughness is shown to give rise to strong HS scattering sources, viz., misfit deformation potential, misfit piezoelectric field in strained HSs [4], and polarization surface roughness scattering in all polar HSs [5]. Thus, interface profile is critical in study of the HS properties. Within the phenomenological model, the interface profile in two-dimensional wave vector space is written as follows	I.GIỚI THIỆU Tán xạ do độ nhám thường là những cơ chế tán xạ quan trọng trong các dị cấu trúc (các HS), đặc biệt là những giếng lượng tử mỏng. Những quá trình này thể hiện nhiều tính chất khác nhau của chúng, chẳng hạn như vận chuyển bên [1], dịch chuyển quang học giữa các vùng con [2], và hình dạng vạch phổ exciton [3]. Người ta thấy rằng độ nhám là những nguồn tán xạ HS mạnh, chẳng hạn như, thế biến dạng khớp sai, trường áp điện khớp sai trong các HS biến dạng [4], và tán xạ nhám bề mặt phân cực trong tất cả các HS có cực [5]. Vì thế, biên dạng bề mặt phân cách rất quan trọng trong việc nghiên cứu các tính chất HS. Trong mô hình hiện tượng luận, chúng ta có thể viết biên dạng bề mặt phân cách trong không gian vector sóng hai chiều dưới dạng
where the form factor FR(qA) depends on A only and is specified by some interface morphology, e.g., Gaussian, [1] power-law, [6] or exponential [7]. A is simply a scaling factor, so fixing the scattering strength, while A appears not	

only in the combination AA but also in FR(qA), so fixing both the strength and angular distribution of scattering.

For any theoretical study of the roughness-related effects, [1, 8] one must adopt some interface profile with A and A as input parameters. It is critical to have A and A individually in order to test the validity of the interface model and the key scattering mechanisms adopted in the theory. It is worth mentioning that for finding two roughness sizes in the literature one adopted the following methods: i) direct measurement by atomic force microscopy and ii) indirect deduction from some measured properties. The former is useful for surfaces that are open on the side of vacuum or air, while the latter for interfaces that are buried between two material layers. There were a number of attempts to get information on two roughness sizes by simultaneously fitting both sizes to optical data, however, so far none of them has been able to separately evaluate A and A. With a simultaneous fitting of A and A to data on conventional features (peak height or linewidth) of the absorption lineshape, one obtained generally not a single

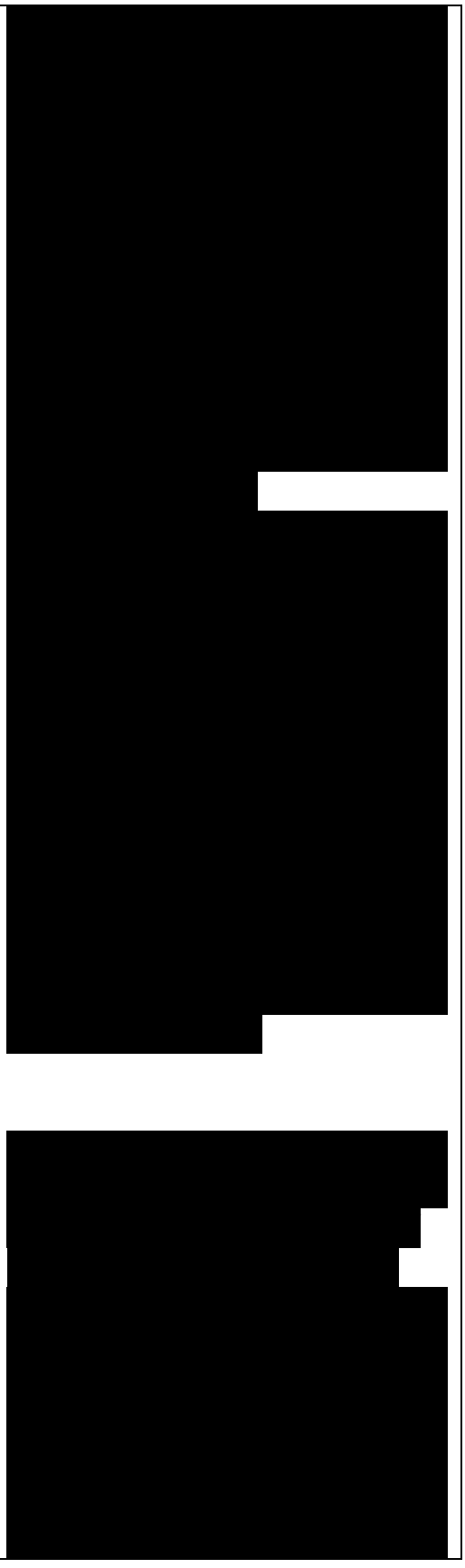
roughness profile, but a set of different profiles with various A and A. It was believed [9] that in principle one is unable to uniquely deduce the interface profile from optical data alone.

On the contrary, in this paper we present an attempt to provide a possibility of individual single-valued estimation of two roughness sizes, merely basing on optical data. For this purpose, we introduce such characteristics of the absorption lineshape that are independent of roughness amplitude, so being a function of correlation length only. As a representative, we examine the ratio between two different values of the absorption-peak height.

II. INTERSUBBAND OPTICAL ABSORPTION IN QUANTUM WELL

II.1. Basic equations

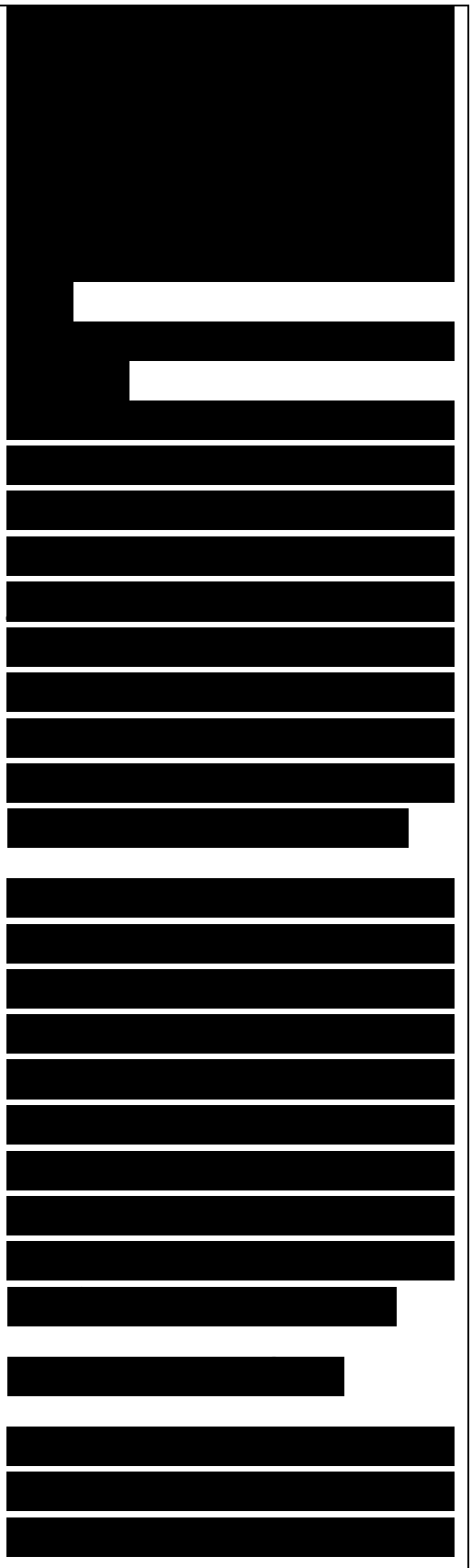
To illustrate our method, we consider the case when only the ground subband in QWs occupied by electrons and the light energy is close to the energy separation between the two lowest subbands hw ~ E10



= E1 — E0 (h is the induced Planck constant). For a symmetric square QW (centered at z = 0) of well width L and potential barrier height Vb, the wave functions are given as follows [10], for the ground state:
and for the first excited state:

where mz is the out of-plane effective masses of the electron in the channel and barrier, respectively. The wave number in the channel is k0,i = \j2mczE0,ifh, and in the barrier k0,i = A/2mb(Vb — E0,1) fh. The absorption quantum efficiency of beam polarized through one well is directly proportional to the oscillator strength, and is given by [10]
here, e is the electron charge, h is the Planck constant, e is the dielectric constant of the well material, m is the effective mass of electrons, c is the velocity of light in vacuum, ns is the two-dimensional carrier density in the well, y is the linewidth and f0-1 is the oscillator strength for the E0 to Ei transition give by

II.2. Surface roughness scattering
The electrons involved in intersubband transition are, in general, subject to various scattering sources: [2, 8, 9]



surface roughness (SR), LO and LA phonons, alloy disorder (AD), and ionized impurities (II). The energy broadening is to be regarded as a measure of the scattering rate. Thus, the observed linewidth is a sum of the partial linewidths (fig 1):
Ytot = YSR + YLO + YLA + YAD + YII. (10)

Here, Y = 2r(E) means the full width at half maximum (FWHM) of the Lorentzian

Fig. 1. The energy broadening: linewidth

lineshape with energy E, i.e., the energy broadening, given by
where the first term arises from intrasubband processes, and second one from intersubband process. As for SR scattering, the interface profile is often assumingly Gaussian. The contribution from SR scattering to the energy broadenings is supplied by [9] ,SR m _m*(AA)2
and

where the in-plane scattering 2D vectors are defined as follows for the intrasubband processes:
and the intersubband one:

The scattering form factors are fixed by the local value of the wave function at the barrier, it holds:

III. ESTIMATION OF INTERFACE PROFILE FROM THE ABSORPTION-PEAK HEIGHT DATA
I

II.1. The absorption-peak height ratio
It was found [2, 9, 11] that in thin QWs, especially at low temperatures, intersubband transition is often dominated by SR scatterings. The electron distribution is determined by the Fermi Energy: EF = h2kF/2m* with kF = y/2nns. It is clear that the roughness-induced APH from Eq. (8, 9, 12, and 13) depend on the parameters of QW (well width and sheet electron density) as well as of interface profile (roughness amplitude and correlation length).

We introduce such lineshape characteristics that depend on a single roughness parameter only, say, correlation length A. A typical example is the ratio between two different values of the absorption-peak height. Following Eqs. (12) and (13), A appears as a scaling factor, it must drops out of the ratio, so this depends on A only:

[redacted]

where the variables of the involved functions are shown explicitely, and (L ,ns) = (L' , n,).

[redacted]

It is worth mentioning that in the literature, one defined the lineshape features and view these as functions of well width and carrier density, which are controllable quantities. Here, we examine the APH ratio and view this from a new aspect, namely, as a function of correlation length, which is a non-controllable quantity. This ratio is inferred from data about the APH as a function of well width and carrier density. So, one can get a singlevalued estimation of A. With a fixed A, one can completely estimate A by a subsequent fit to some APH value. In other word, one can single-valued estimate the interface profile.

Thus, with the two-step fitting one archives an individual single-valued evaluation of the two roughness parameters that employs data on one observed property only: intersubband absorption alone or lateral mobility alone [12].

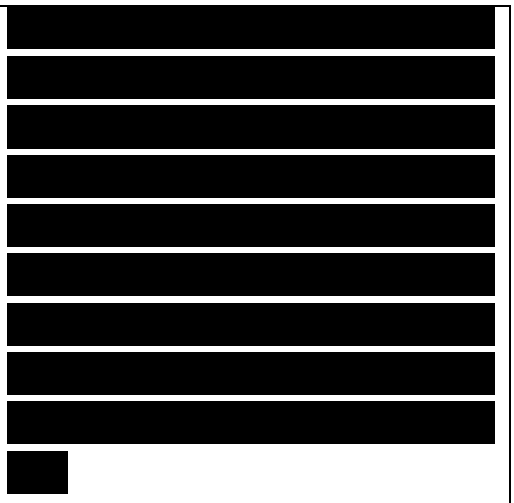
III.2. Numerical results

In order to illustrate the above method, we deduce the interface profile from intersubband APH in the QW made of GaAs/Al0.3Ga0.7As [2, 9] with barrier height: Vb = 210 meV and effective mass: m*/m0 = 0.0665, mb/m0 = 0.09155.

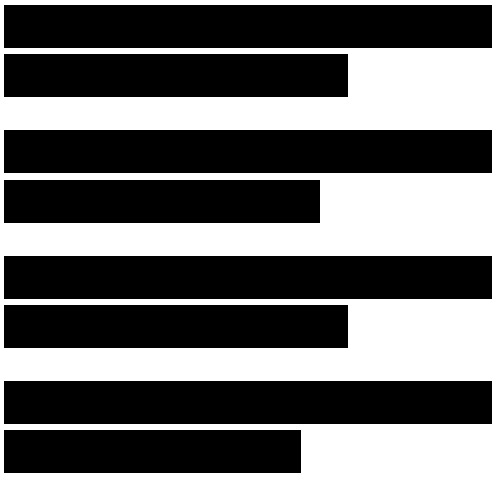
Fig. 2. The absorption-peak height ratio in Eq. (17), R(A) = R(L, ns, L', nS; A) is plotted versus correlation length A for the GaAs/Alo.3Gao.7As QW.

In Fig. 2, the APH ratio in Eq. (17), R(A) = R(L,ns,L',nS;A) is plotted versus correlation length A for the GaAs/Al0.3Ga0.7As QW. The transition is assumed to be dominated by the SR scattering mechanism [2, 9] (marked by

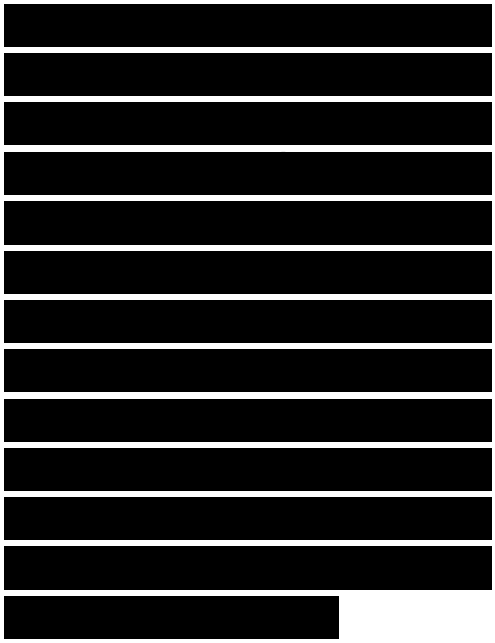
solid lines). The QW parameters are given in Refs. [2, 9] and taken from Fig. 4 of Ref. [13] (well width in A and sheet electron density in 1011 cm-2) as follows:



a) L = 90, ns = 13.5; L' = 70, nS = 10.5 and Rexp = 2.34.
b) L = 100, ns = 15; L' = 80, nS = 12 and Rexp = 2.54.
c) L = 100, ns = 15; L' = 70, nS = 10.5 and Rexp = 3.74.
d) L = 90, ns = 13.5; L' = 60, ri's = 9 and Rexp = 2.41.



In Fig. 3, the absorption-peak height peakn(A) = peakn(L,ns;A;A) is plotted versus roughness amplitude A with the correlation length deduced from Fig. 2: A = 71 A and QW parameters: a) L = 100 A, ns = 15 x 1011 cm-2 and peakn = 34.7%. b) L = 90 A, ns = 13.5 x 1011 cm-2 and peakn = 30.6% and c) L = 80 A, ns = 12 x 1011 cm-2 and peakn = 26.6%. From here, we deduce the value of the roughness amplitude is A = 1.9 A.



IV. CONCLUSION

In contrast to the earlier belief, we have proposed an efficient method for individual estimation of two sizes of the interface profile, based on the processing of optical data by a two-step fitting of

Fig. 3. The absorption-peak height peakv (A) = peakv (L, ns; A; A) is plotted versus roughness amplitude A with the correlation length deduced from Fig. 2.

(i) to the absorption-peak heights ratio at one point, and then
(ii) to the absorption-peak height at one point.

The merit of our method is to provide a single-valued estimation of the interface profile. This is also economical since one needs two experimental points rather than the whole functional dependence at many points.