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EFFECT OF IONIZATION RADIATION ON SEMICONDUCTOR LASER PARAMETERS

Abstract
The reliability of laser diodes for use in space applications is studied. In the experiment, the field of gamma radiation was chosen as the radiation environment affecting the laser diodes, and the effect of radiation on the noise parameter of the semiconductor laser and their reproducibility were studied.
Keywords. Electron-hole pair, ionizing effect, displacement damage semiconductor laser,the parameters of the laser diode, noise density, gamma radiation, radiation dose.

ВЛИЯНИЕ ИОНИЗАЦИОННЫХ ИЗЛУЧЕНИЙ НА ПАРАМЕТРЫ ПОЛУПРОВОДНИКОВОГО ЛАЗЕРА

Аннотация
Исследована надежность лазерных диодов для использования в космической технике. В эксперименте в качестве радиационной обстановки, воздействующей на лазерные диоды, было выбрано поле гамма-излучения, и исследовано влияние излучения на шумовые параметры полупроводникового лазера и их воспроизводимость.
Ключевые слова.Электронно-дырочная пара, эффект ионизации, смещение повреждение, полупроводниковый лазер, параметры лазерного диода, гамма-излучение, доза облучения.

YARIMO‘TKAZGICHLI LAZER PARAMETRLARIGA IONIZATSION NURLANISHLAR TA’SIRI

Annotatsiya
Kosmik ilovalardan foydalanish uchun lazer diodlarning ishonchliligi o'rganiladi. Bugungi kunga qadar lazer diodlarining turli parametrlariga ionizatsion nurlanishlar ta’siri o’rganilishiga qaramay, bu sohada hali tushuntirilmagan jihatlar ko’p. Tajribada lazer diodlariga ta’sir etuvchi radiatsion muhit sifatida gamma nurlanish maydoni tanlandi hamda yarimo’tkazgichli lazerning shovqin parametriga nurlanish ta’siri va ularning qayta tiklanuvchanligi o’rganildi.
Kalit so‘zlar. Elektron-teshik jufti, ionizatsion ta’sir,siljish shikastlanishi, yarimo’tkazgichli lazer, lazer diodining parametrlari, shovqin zichligi, gamma nurlanish, nurlanish dozasi.

Kirish. Kosmik nurlanishning yarimo'tkazgichli materiallarga olib keladigan asosiy shikastlanish mexanizmlari ionlanish shikastlanishi, sirt shikastlanishi va siljish shikastlanishidir [1]. Ionlashning shikastlanishi gamma nurlanishidan kelib chiqadi va ionlashtiruvchi nurlanish ortiqcha elektron-teshik juftlarini hosil qiladi, bu esa o'tkazuvchanlikni oshishiga olib keladi [2-7]. Ionlash shikastlanishi rentgen nurlari, ultrabinafsha nurlanish yoki bilvosita ikkilamchi zarrachalar orqali ham yuzaga kelishi mumkin [8-10]. Yarimo’tkazgich materialning ionlanishi ortiqcha zaryad tashuvchilar, elektr va magnit maydonlarning o'zgarishi va kimyoviy ta'sirlarni ishlab chiqarish orqali elektr o'tkazuvchanligini oshishiga olib keladi [11].

Siljish shikastlanishi atomlarning ko’chishi ta’sirida materialda nuqsonlarni keltirib chiqaradi va bu nuqsonlar radiatsiyaviy bo'lmagan rekombinatsiya markazlari sifatida ishlaydi, bu esa tashuvchining ishlash muddatini qisqarishiga olib keladi [1]. Har uchta zarar mexanizmi lazer manbasining chiqish quvvatining kamayishiga va markaziy to'lqin uzunligining o'zgarishiga olib keladi [17-22].

Lazer diodlarini ishchi rejimini aniqlash uchun o’rganilayotgan muhit lazer diodiga qanday ta’sir etishini bilish va uning parametrlaridagi o’zgarishlarni taqqoslab ko’rish kerak.O’tkazilgan qator tajribalar natijalariga ko’ra gamma nurlanishning lazer diodlarining shovqin xarakteristikasiga tasiri 10^5-10^9 rad dozalarda kam o’rganilgan.

Shu sababli ushbu ishda radiatsiya nurlanishining yarimo’tkazgichli lazerlarga ta’siri hamda gamma nurlanishning 10^5-10^9 rad dozalari uchun lazerning shovqin zichligi xarakteristikasi o’rganildi.

Experiment va natijalar. Yarimo’tkazgichli lazerlarda shovqin xarakteristikasini o’lchash uchun bajarilgan laboratoriyaning asosiy maqsadi lazerlardan turli muhitlarda foydalanish natijasida yuzaga keladigan lazerning aktiv elementidagi buzilishlarni aniqlash va ularni kamaytirishdan iborat. Yarimo’tkazgichli lazer diodlariga gamma nurlanish ta’sirini o’lchash maqsadida olingan GaAs turdagi yarimo’tkazgichli lazeri gamma nurlanishga qo’yildi. Dastlab birinchi lazer uchun gamma nurlanishning 10^5 rad miqdorida gamma nurlanish berildi. Bu holatda kanal quvvati 120 R/s, nurlanish vaqti esa 13 minutni tashkil qilad

Lazer nurlanishidagi shovqinlarni eksperimental tadqiq etishda, odatda, nurlanish shovqinining spektral zichligi o`lchanadi. Buning uchun kam shovqinli qabul qilgichdan, masalan, lazer nurlanishini qabul qiladigan qiladigan FEK dan elektr signali tashkil etuvchilari (o`zgarmas tashkil etuvchi $U_=$ va o`zgaruvchan tashkil etuvchi $U_\sim$) o`lchanadi. Bunda nurlanish shovqinining spektral zichligi quyidagi formula bo`yicha hisoblanadi [23]:

$$S(f)=\frac{U_{\sim}}{U_{=}\cdot\Delta f^{1/2}}\quad[G\,s^{-1/2}],$$

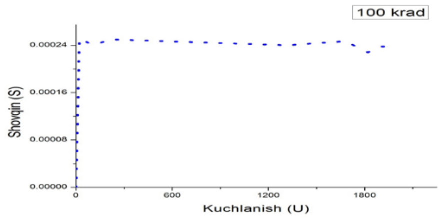
Lazer diiodlarining shovqin parametriga gamma nurlanish ta’sirini o’rganishda bajarilgan tadqiqot quyidagi bosqichlarda amalga oshirildi:

1.Radiatsion nurlanishlar ta’sirisiz lazer diodlarining shovqin zichligi o’rganildi.

2.Radiatsion nurlanishlar holatida gamma nurlanish dozasining o’sib borish tartibida LD ning shovqin zichligi o’rganildi.

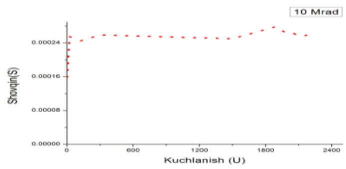
3.Radiatsion nurlanishlar ta’siri to’xtatilgandan so’ng LD shovqin zichligi qayta tiklanuvchanligi o’rganildi.

1-rasmda gamma nurlanishning 100 krad nurlanish dozasida olib borilgan tajriba natijalari keltirilgan. Undan ko’rinadiki, nurlanish shovqin zichligi fotoko’paytirgichdan chiqayotgan elektr signalining o’zgaruvchan tashkil etuvchisiga bog’liqligi to’g’ri chiziq holatidan deyarli chetlashmaydi. Nurlanish dozasining past qiymatlarida LDning aktiv element qismidagi buzilish miqdori deyarli sezilmaydi.



1-rasm. *100 krad nurlanish uchun shovqin zichligi xarakteristikasini fotoko’paytirgichdan chiqayotgan elektr signalining o’zgaruvchan tashkil etuvchisiga bog’liqligi.*

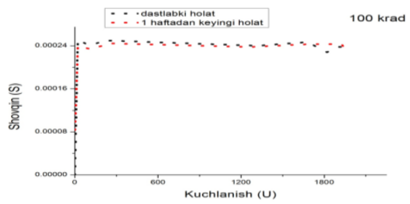
2-rasmda 10Mrad nurlanish uchun shovqin zichligi xarakteristikasini fotoko’paytirgichdan chiqayotgan elektr signalining o’zgaruvchan tashkil etuvchisiga bog’liqligi keltirilgan.Bunda nurlanish doza miqdori oshib borgan sari shovqin parametrining to’g’ri chiziqdan chetlashishi kuzatildi. FEKdan chiqayotgan elektr signalining o’zgaruvchan tashkil etuvchisining qiymati yuqori nuqtaga yetganda buziishlar miqdori ortganligi kuzatildi. Buning sababi asosiy bo’lmagan zaryad tashuvchilar miqdorining ortishi bilan tushuntiriladi [24].



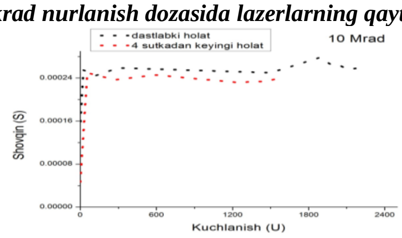
2-rasm. 10 Mrad nurlanish uchun shovqin zichligi xarakteristikasini fotoko’paytirgichdan chiqayotgan elektr signalining o’zgaruvchan tashkil etuvchisiga bog’liqligi.

Lazerlarni nurlanishga chidamliligini oshirish bir tomondan xarajat sarfini kamaytirsa, ikkinchi tomondan ulardan foydalanish imkoniyatini oshiradi.

O’tkazilgan tajriba davomida nurlantirilgan lazerlarning tiklanuvchanligini o’rganish maqsadida radiatsiya vaqtidan 4-7 sutka davomida natijalar qayta olindi. 3-rasmda 100 krad nurlanish dozasi uchun o’lchangan lazerning 7 sutkadan keyingi holati qayta keltirilgan. Tajriba natijalariga ko’ra har ikki holat o’rtasida sezilarli farq kuzatilmadi. 4-rasmda 10 Mrad doza miqdori uchun bajarilgan tajriba 4 sutkadan so’ng qayta o’lchash natijalari berilgan. Ikki holatdagi grafiklar sezilarli darajada farq qiladi. Buning sababi nurlanish dozasining yuqori qiymatlarida aktiv sohada ortgan buzilishlar miqdori 4 sutkadan so’ng yana muqobil qiymatga qaytishidir.



3-rasm.100 krad nurlanish dozasida lazerlarning qayta tiklanuvchanligi



4-rasm.10 Mrad nurlanish dozasida lazerlarning qayta tiklanuvchanligi

Xulosa va takliflar. Tajriba natijalariga ko’ra, gamma nurlanishning 10^5 rad miqdorida lazerlarda buzilishlar deyarli kuzatilmadi. Qisman buzilishlar ro’y berdi, xona haroratida dastlabki ish rejimini qayta tikladi. Gamma nurlanish doza miqdori oshib borgan sari yarimo’tkazgichli lazerlarning shovqin zichligi xarakteristikasi ham oshib borishi kuzatildi.

Gamma nurlanishning 10^8 raddan yuqori dozalarda biz foydalanayotgan lazerlarning ish rejimida buzilishlar miqdori ortdi. Lazerlarning ichki va tashqi qoplamalarida plastmassadan yasalgan tarkiblarning parchalanishi kuzatildi. Bu holatda lazerlardan natija olishga erishib bo’lmadi.

Yarimo'tkazgichli GaAs turdagi lazerlar gamma nurlanishning 10^5-10^7 rad doza miqdorigacha nisbatan kam buzilishlarni namoyon qildi. Gamma nurlanishning 10^8-10^9 rad doza oralig'ida esa buzilishlar miqdori ortib shovqin xarakteristikasi kuchaydi.

Atrof-muhitdan keladigan nurlanishlar lazer parametrlariga ta'sir etib nurlanishlar miqdorini ortishi lazer ishchi rejimini buzilishiga ham olib keladi. Nurlanishlar ta'sirini kamaytirish maqsadida lazerlarning sirt qoplamasini nurlanishga chidamliligini oshirish hamda nurlanish ta'sirini kamaytirish choralarini ishlab chiqish zarur.

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