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DOI: 10.21776/ub.jpacr.2016.005.03.266 J. Pure App. Chem. Res., 2016, 5 (3), 148-156 26 September 2016 X The journal homepage www.jpacr.ub.ac.id p-ISSN : 2302 – 4690 | e-ISSN : 2541 – 0733 Optical Properties of Nd3+ Doped Phosphate Glasses at 4F3/2 ? 4I11/2 Hypersensitive Transitions J. Rajagukguk1,2*, M. Djamal1, R. Hidayat1, Suprijadi1, A.

Aminuddin3, Y. Ruangtaweep4, J. Kaewkhao4 1Faculty of Mathematics and Natural Sciences, Institut Teknologi Bandung, Indonesia 40132 2Faculty of Mathematics and Natural Sciences, Universitas Negeri Medan, Indonesia 3Department of Physics, Universitas Pendidikan Indonesia, Indonesia 4Center of Excellence in Glass Technology and Materials Science, Nakhon Pathom Rajabhat University, Thailand *Corresponding email : juniastel@yahoo.com Received 20 May 2016; Revised 20 September 2016; Accepted 26 September 2016 ABSTRACT The lasing transition 4F3/2 ? 4I11/2 for Nd3+ doped phosphate glass centered around 1.05 – 1.07 ? m is referred as hypersensitive transition.

The radiative properties such as effective line width (? ? eff), radiative transition probability (AR), branching ratio (? R), radiative lifetime (? R), quantum efficiency (?) and stimulated emission cross section have been obtained for several phosphate and fluorophosphate glass contained Nd3+. The experimental and calculated oscillator strength were used to analysis Judd-Ofelt parameters (? 2, ? 4 and ? 6) also to predict the quality of factor ? .

The phosphate glass material with the approximately 69P2O5-15Na2O-15K2O-1Nd2O3 composition at 4F3/2 ? 4I11/2 transition is suitable for laser medium. The enhanced radiative transition probability as well as branching ratio and stimulated emission cross section in this glass are 3694 s-1, 52% and 8.67 x10-20 cm2 respectively. As in commercial laser, the magnitudes of the emission cross section in this study achieved in the range 4.0-5.0 x 10-20 cm2.

Keywords: phosphate glass, Nd3+, lasing transition INTRODUCTION Phosphate glass is one of the most famous glasses among glasses as host matrix medium gain Nd3+ of ion laser. It is well known due to phosphate glass able to contain higher concentrations of Nd3+ ions and still have excellent uniformity relative to other oxide glasses.

In other hand, phosphate glass present high strength, low concentration self-quenching, low ESA, low thermal expansion coefficient, long fluorescence lifetime and good optical thermal behavior [1]. Studies on phosphate glass laser transitions at the 4F3/2 ? 4I11/2 level have produced larger emission cross section, slight emission line-width, higher gain, higher energy storage capacity and minimum optical losses at a wavelength ? 1.06 ? m for several applications [2].

Phosphate glass laser contain Nd3+ has produced high peak power (? 1014W), high energy output system (106J) (for nuclear fusion research)[3], optical amplifiers, photosensitivity, optical storage and Faraday rotators[4]. Performances of the Nd3+ doped phosphate glass are obtained by calculation, measurement, characterization and analysis results.

The optical parameters of the laser medium were observed such as absorption wavelength peak, energy band and absorption cross section. These parameters used to determine the intensity parameters (? 2, ? 4, ? 6), oscillator strength, line-width wavelength J. Pure App. Chem. Res., 2016, 5 (3), 148-156 26 September 2016 26 September 2016 X The journal homepage www.jpacr.ub.ac.id p-ISSN : 2302 – 4690 | e-ISSN : 2541 – 0733 149 effective, stimulated emission cross section, fluorescence lifetime, and quantum efficiency of the radiative.

In other hand, non-radiative transition process and quenching effect in the surrounding of Nd3+ ions should be important for observation. G.A. Kumar et al [5] explained that to achieve higher quantum efficiency on laser intensity, the non radiative process by multiphonon relaxation should be minimized. P.

Godlewska et al [6] carried out an investigation on the optical absorption and luminescence properties of Nd3+ ion in variety of phosphate glasses including diphosphate, orthophosphate, and metaphosphate. Among the phosphate group, metaphosphate glasses are the most attractive host due to longer Nd-Nd distance appears and higher luminescence lifetime.

Alleged that this kind of phosphate indicating high active-particles concentration to decrease of the self-quenching of luminescence. The Emission transition in Nd3+ doped phosphate glasses produces three transitions in the NIR range where the 4F3/2 ? 4I11/2 transition is the strongest emission than the others.

However, the wavelength peak of the hypersensitive transition is not exactly the same for each different glass compositions, such as NaH2PO4H2O-H3BO3-BaF2-NdF2[7] reported that the emission wavelength peak at 1057 nm, 55P2-17K2-11Mg-9Al2-6BaF-2Nd2O3 at 1053 nm [2], 60P2O5-13ZnO-5Al2O3-20La2O3- 2Nd2O3 at 1060 nm[8], 69P2O5-15Na2O-15Li2O-1Nd2O3 at 1069 nm [9], 69P2O5-22,5Na2O- 7,5Li2O-1Nd2O3 at 1071 nm[9] and 93NaH2PO4H2O-5BaF2 1Nd2O3 at 1055 nm[10].

Generally, the high fluorescence properties of laser medium could be enhanced by determining the novelty of composition and structure of the host matrix glass. This paper investigates several the laser glass medium began from the glass former in phosphate, modifier, intermediate structure and variation of Nd3+ ion concentration. Moreover, study about the optical properties as a function of both concentration and structure composition had been explained in each section below.

DISCUSSIONS Absorption properties of Nd3+ doped phosphate glasses Before the emission and radiative properties were determined, the first was measured absorption spectra of Nd3+ ions in these phosphate glasses. In several papers reported that the shapes and position of the absorption transition from the ground state to excited state were almost the same.

However, some papers also have slight differences in the amount of absorption band and the wavelength shift of the absorption peak positions due to variation of the glass composition. One form of the absorption spectrum of Nd3+ in phosphate glasses that has been reported was shown in Figure 1 [11]. In these spectrum obtained eight absorption wavelength peaks of 428, 465, 524, 582, 685, 744, 804, and 869 nm with the strongest absorption band occurs at 582 nm followed by 804 nm could be assigned to the transition of 4I9/2 ? 2G5/2,4G5/2 and 4I9/2 ? 2H9/2,4F5/2 respectively. J. Pure App. Chem. Res.,

2016, 5 (3), 148-156 26 September 2016 26 September 2016 X The journal homepage www.jpacr.ub.ac.id p-ISSN : 2302 – 4690 | e-ISSN : 2541 – 0733 150 Figure 1. Absorption bands of 0.5 mole% Nd3+ doped phosphate glasses, LHG-8[11] These absorption wavelength peaks were slightly different compared to the absorption bands of papers that have been reported previously [2,6,9,12].

The initial absorption of Nd3+ doped lithium phosphate glass in visible range occurs of 4I9/2 ? 4I11/2+4D3/2+4D5/2 transition around at 360 nm obtained by M. Seshadri et al [9]. The absorption peaks shifted caused by differences in the composition of the host glass matrix. Each composition of the modifier in the glass can changes the Nd3+ structure of ion, therefore affect the positions of the energy and oscillator strength of each transitions as shown in Table 1.

Oscillator Strength and Judd-Ofelt Parameters The intensity of transition among J-manifolds 2s+1Lj for rare earth (RE) ions calculated by using of Judd-Ofelt theory. The absorption band and wavelength range of Nd3+ doped phosphate glasses used to identify the radiative transition, such as probabilities transition, effective bandwidth, branching ratio and lifetime of 4F3/2 ? 4I9/2, 4F3/2 ? 4I11/2 dan 4F3/2 ? 4I13/2 transitions.

J-manifold transitions in RE ion are generated by induced electric dipole transitions, despite of the weak magnetic dipole transitions still occur in the band spectra [13]. The intensity parameters ? ? (? = 2, 4 and 6) calculated from oscillator strength for electric dipole transition have been explained before [14]. The intensity produced by the absorption spectrum of Nd3+ doped phosphate is strongly influenced by the condition of the host matrix.

Some factors that affect the intensity were the chemical properties of metals, variation of the glass composition. On the other hand, the active ions-metal bond can be changed by the concentration of each compound that affects the intensity. The values of both oscillator strength of ground state 4I9/2 to excited state for seven higher intensity transitions summarized from several papers about Nd3+ doped phosphate glasses shown in Table 1. The general hypersensitive transitions in the Nd3+ doped phosphate glass i.e.

4I9/2 ? 4G9/2, 4I9/2 ? 4G7/2, 4I9/2 ? 4G5/2,2G7/2, 4I9/2 ? 4F9/2, 4I9/2 ? 4F7/2, 4I9/2 ? 4F5/2, and 4I9/2 ? 4F3/2. In Table 2 showed that the absorption transition 4I9/2 ? 4G5/2,2G7/2 centered on around of 582-586 nm expressed as hypersensitive transitions due to the oscillator strength at this transition is bigger than that all of absorption transitions. Table 1.

Absorption transitions (from the ground state 4I9/2 to excited state), and oscillator strength for x Nd3+ (mole%) doped phosphate glass Initial glass 4I9/2 ? 4G9/2 4G7/2 4G5/2,2G7/2 4F9/2 4F7/2 4F5/2 4F3/2 xNd3+ fexp fcal fexp fcal fexp fcal fexp fcal fexp fcal fexp fcal fexp fcal PKFBAN[1] 1.0 2.8 1.9 4.1 3.2 19.0 19.0 0.4 0.5 6.8 7.4 7.4 6.8 1.6 2.0 PKMAFN[2] 2.0 4.0 2.6 4.9 4.6 28.3 28.3 0.8 0.7 10.0 9.7 8.6 9.1 2.9 2.7 J. Pure App. Chem. Res.,

2016, 5 (3), 148-156 26 September 2016 26 September 2016 X The journal homepage www.jpacr.ub.ac.id p-ISSN : 2302 – 4690 | e-ISSN : 2541 – 0733 151 Initial glass 4I9/2 ? 4G9/2 4G7/2 4G5/2,2G7/2 4F9/2 4F7/2 4F5/2 4F3/2 xNd3+ fexp fcal fexp fcal fexp fcal fexp fcal fexp fcal fexp fcal fexp fcal PKMABFN[2] 2.0 4.5 2.7 5.6 4.8 28.8 28.8 0.9 0.7 10.3 9.4 7.9 9.2 3.1 3.0 KumarA[5] 2.0 7.6 8.0 11.1 10.0 47.1 50.0 3.3 2.8 14.4 15.0

14.0 11.5 3.4 3.8 KumarB[5] 1.0 3.6 3.1 7.3 7.8 27.1 30.0 2.3 2.0 8.4 8.0 8.9 10.0 2.5 2.0 KumarC[5] 1.0 3.0 2.5 7.3 8.0 26.4 28.0 2.5 2.0 8.9 9.0 8.4 7.6 2.8 3.0 G.AKumar A[7] 2.0 5.7 - 5.4 - 17.2 - 3.5 - 7.4 - 5.7 - 2.6 - G.AKumar B[7] 2.0 7.7 - 6.2 - 16.8 - 2.6 - 8.7 - 6.8 - 2.3 - G.AKumar C[7] 2.0 6.2 - 5.5 - 15.1 - 2.7 - 8.1 - 7.7 - 2.6 - PKMFAN[12] 1.0 2.7 1.5 3.2 2.6 16.1 16.1 0.8 0.4 5.2 5.6 5.6 5.2 1.2 1.5 PKSFAN[12] 1.0 3.6 2.2 4.9 3.6 20.7 20.9 0.7 0.6 7.8 8.1 8.0 8.0 2.3

2.2 J.H. Choi[15] 1.0 2.6 1.5 5.8 5.9 12.5 12.5 0.7 0.5 6.6 6.4 6.8 7.2 2.9 3.1 A.S.Rao A[16] 1.0 1.6 5.1 6.2 7.6 49.6 49.5 1.5 1.5 19.8 18.6 20.5 18.6 3.7 4.4 A.S.Rao B[16] 1.0 2.9 5.2 6.5 7.9 50.8 50.7 1.5 1.6 20.9 19.0 21.0 19.0 4.0 4.7 A.S.Rao C[16] 1.0 1.5 5.3 6.5 8.1 52.8 52.6 1.3 1.6 21.7 19.2 21.7 19.2 3.7 4.7 RAO A[17] 1.0 1.5 2.7 6.2 9.4 52.8 51.5 1.4 1.6 21.3 22.2 19.9 19.4 3.7 3.8 RAO B[17] 1.0 1.6 1.9 6.5 5.7 50.7 51.8 1.5 1.5 21.7 22.5 21.0 20.5 4.0 3.8

RAO C[17] 1.0 1.5 0.9 6.4 7.0 52.7 52.5 1.7 1.7 21.5 21.0 20.8 20.7 3.7 3.5 PKBAN[18] 1.0 4.9 3.3 6.3 5.9 35.2 35.2 0.9 0.9 12.4 12.1 10.9 11.6 3.9 3.6 PKBFAN[18] 1.0 5.2 3.3 6.6 5.6 25.2 25.2 0.7 0.8 10.8 10.9 10.9 11.1 3.8 3.9 PKBAFN[18] 1.0 4.7 2.9 5.7 5.0 27.6 27.7 0.7 0.8 9.8 10.3 10.4 10.0 2.7 3.2 PKSAN[19] 1.0 3.1 2.2 4.6 3.7 24.0 24.0 0.7 0.6 9.1 8.8 7.4 8.0 2.5 2.1 PKSAFN[19] 1.0 3.3 2.4 44.8 4.2 25.6 25.6 0.6 0.6 9.2 8.4 7.1 8.2 2.4 2.6 PKSABFN[19] 1.0

3.4 2.3 5.0 4.0 24.6 24.7 0.6 0.9 9.0 8.4 7.2 8.0 2.2 2.4 In general, experiment nor theoretical oscillator strength value almost similar except of that have distinction around 3 x 10-6 [5]. The highest of the oscillator strength value for hypersensitive transition achieved by A.S.

RAO and RAO initial glasses with glass composition of 50(NaPO3)6-10Zn3(PO4)2-10BaF2-9AlF3-20KF and 40(NaPO3)6-

10BaF2-9ZnF2-B2O3-20KF respectively [16,17]. The oscillator strength magnitudes also used to determine of the best of intensity parameters ? ? (? =2,4,6) by fitting of the standard least- square values in both theoretical and experimental oscillator strength. Judd-Ofelt parameters of Nd3+ in various glasses phosphate are compared in Table 2. As presented by S.S.

Babu et al [2,20], ? 2 parameter defines the covalence bonding of metal-ligand, in other words the ? 2 value is increase by lowered the symmetry of Nd3+ ion ligand field. Whereas, ? 4 and ? 6 parameters were identified as the rigidity of host matrix. Table 2. Judd-Ofelt parameters (x 10-20) and spectroscopic quality factor (? 4/ ? 6) of the excellent concentration of Nd3+ (x) doped phosphate glasses based Glasses compositions xNd3+ (mole%) Parameters 55.5P2O5-14K2O-6KF-14.5baO-9Al2O3[1] 1.0 4.92 3.67 5.26 0.70 46,6P-16.7K-13.8Mg-8.4A-3.45AlF-2Nd[2] 2.0 7.66 5.15 6.99 0.73 55P2-17K2-11Mg-9Al2-6BaF-2Nd[2] 2.0 7.34 5.97 6.69 0.89 68P2O5-20Na2SO4-10BaF2[5] 2.0 3.6 8.7 6.4 1.35 68NaH2PO4H2O-20H3BO3-10BaF2-2NdF2[7] 2.0 2.78 5.00 7.04 0.71 60P2O5-13ZnO-5Al2O3-20La2O3[8] 2.0 4.53 3.67 4.02 0.91 69P2O5-15Na2O-15Li2O[9] 1.0 4.32 3.66 6 0.61 69P2O5-15Na2O-15K2O[9] 1.0 7.68 8.96 11.71 0.76 88NaH2PO4H2O-5LiF -5BaF2[10] 2.0 2.47 7.0 7.55 0.92 55P2O5-17K2O-12SrO-6SrF2-9Al2O3[12] 1.0 5.24 4.30 5.81 0.74 0.1Al(PO3)3-0.1Ba(PO3)2-0.4(Mg-Ba)F2[15] 2.0 1.83 4.73 4.19 1.13 50(NaPO3)6-10Zn3(PO4)2-10BaF2-9AlF3-20KF[16] 1.0 18.83 8.16 15.86 0.51 40(NaPO3)6-10BaF2-9ZnF2-B2O3-20NaF[17] 1.0 22.41 4.43 17.83 0.29 J. Pure App.

Chem. Res., 2016, 5 (3), 148-156 26 September 2016 26 September 2016 X The journal homepage www.jpacr.ub.ac.id p-ISSN : 2302 – 4690 | e-ISSN : 2541 – 0733 152 Glasses compositions xNd3+ (mole%) Parameters P2O5+K2O +BaO +Al2O3[18] 1.0 9.23 7.0 8.74 0.8 58.5P2O5-17K2O-14.5SrO-9Al2O3[19] 1.0 6.74 3.86 6.35 0.61 20Al(PO3)3-60MgF2-20NaF-1NdF3[21] 1.0 4.63 2.55 6.79 0.37 Na2O-Al2O3-B2O3[22] 1.3 3.53 6.57 5.12 1.28 40(NaPO3)6-9ZnF2-20B2O3-10(BaF2- KF -LiF)[23] 1.0 22.47 6.78 11.25 0.60 The ? 2 parameter for 40(NaPO3)6-9ZnF2-20B2O3-10(BaF2-KF-LiF) or Glass-C [23] and 40(NaPO3)6-10BaF2-9ZnF2-B2O3-20NaF or RAO-B [17] glasses are observed to be relatively higher than other glasses. The ? 2 magnitude is influenced by the values of the oscillator strength were higher in hypersensitive transition.

The higher ? 2 magnitude at Glass-C and RAO-B reflects of asymmetry and covalency bond at Nd3+ ions were strong [2]. This phenomenon also explains that in this glasses has a higher nephelauxetic effect caused by the asymmetry of the crystal field and the changes in the energy difference between the 4f configurations [20,24].

The distribution of ? ? parameters generated are different one others and depends on host ligand even though have the same of Nd3+ ion concentration. As shown at Table 2 is found ? 2 > ? 4 > ? 6 form [9,10], ? 2 > ? 6 > ? 4 [2,13,18,19,21,25,26], ? 6 > ? 2 > ? 4 [1,23] and ? 4 > ? 6 > ? 2 [5,10,17]. The larger value of ? 2 for both types reflects on the higher sensitivity of each glass.

In addition, the ? 6 parameter is found higher in [1,10,9,21] glasses than that phosphate glasses indicating a higher of the rigidities of the host matrix due to distance between Nd3+ ions and the ligands increase [9,25]. The spectroscopic quality factor has been determined by using equation ? = ? 4/ ? 6 to predict the branching ratios, ? R at lasing transitions.

In Table 2 listed the ? values of the several Nd3+ doped phosphate glass compositions and the values are varied each glass. Generally, the spectroscopic quality factor in Table 2 obtained smaller than one except [10,18,22]. The lower ? values indicate that advantageous of intensity for the 4F3/2 ? 4I11/2 lasing transition but instead of 4F3/2 ? 4I9/2 [26].

Radiative properties of 4F3/2 ? 4I11/2 transition The emission spectra shape and values of the Nd3+ doped glass excited by 582 nm at wavelength range 800-1600 nm is shown in Fig. 2. In Fig. 3 also shown the energy level of Nd3+ transitions that excited from ground state absorption 4I9/2 to upper state 4G5/2,2G7/2 or 4F5/2, 2H9/2 then extended to relaxation state 4F3/2 by the non-radiative.

The radiative emission properties of Nd3+ in phosphate host glasses were predicted by using absorption bands and ? ? parameters as presented at Table 4. The values of the excitation wavelength required to investigation of lasing wavelength peak (? p) and prediction of effective line-width (? ? eff), radiative transition probability (AR), branching ratio (? R), radiative lifetime (? R), quantum efficiency (?) by using expressions [15,27].
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2016, 5 (3), 148-156 26 September 2016 26 September 2016 X The journal homepage www.jpacr.ub.ac.id p-ISSN : 2302 – 4690 | e-ISSN : 2541 – 0733 153 Fig. 2. Emission spectra of Nd3+ doped glasses excited by 582 nm Fig. 3. Energy level of Nd3+ doped glass transitions [28,29] There are three transitions occurs in the emission spectra of Nd3+ doped phosphate glasses that consistent begins from 4F3/2 manifold leading to 4I9/2 , 4I11/2 and 4I13/2 levels respectively.

However, some authors have reported four transitions including the 4F3/2 ? 4I15/2 transition [4,9]. In Table 3 it showed specially the radiative transition for 4F3/2 ? 4I11/2 level providing the range of wavelength peaks at 1051-1070 nm. The main radiative hypersensitive transition fits with the commercial laser wavelength by N21, N31, LG-770; LG-750 and LGN in Table 1 are glass compositions in references [1,2]. Whereas, laser commercial wavelength which conducted by LHG-5 and LHG-6 has already matched with glass compositions in reference [12]. Table 3.

Excitation wavelength (? exc), wavelength peak (? p), effective bandwidth (? ? eff), radiative transition probabilities (AR), stimulated emission cross section (? e), branching ratio (? R), radiative lifetime (? R) and experimental lifetime (? exp) for the hypersensitive Nd3+ doped Phosphate glasses at 4F3/2 ? 4I11/2 emission transition Phosphate Glass Compositions 4F3/2 ? 4I11/2 transition ? ex (nm) ? p (nm) ? ? eff (nm) AR (s-1) e(p) x10- 20 (cm2) R R (s) ? exp (? s) 55.5P2O5-14K2O-6KF-14.5BaO-9Al2O3[1] - 1053 27.97 2870 3.67 - 348 286 46,6P-16.7K-13.8Mg-8.4A- 3.45AlF-2Nd[2] 355 1053 29.5 - 4.40 0.64 - 196 55P2-17K2-11Mg-9Al2-6BaF- 2Nd[2] 355 1053 30.7

- 4.46 0.65 - 210 68P2O5-20Na2SO4-10BaF2[5] 807 1055 21 1608 5.9 0.58 250 168 78NaH2PO4H2O-10H3BO3-10BaF2- 2NdF2[7] 807 1057 27.5 1563 3.7 0.531 271 160 68NaH2PO4H2O-20H3BO3-10BaF2- 2NdF2[7] 807 1057 28.5 1825 4.4 0.536 276 180 58NaH2PO4H2O-30H3BO3-10BaF2- 2NdF2[7] 807 1057 29.3 1871 4.7 0.547 320 200 60P2O5-13ZnO-5Al2O3-20La2O3[8] 819 1060 28.4 1034 - 0.49 320 117 69P2O5-15Na2O-15Li2O[9] 514 1069 36.23 1833 3.73 0.52 - 79 69P2O5-30Na2O [9] 514 1069 39.37 2463 5.48 0.52 - 61 69P2O5-15Na2O-15K2O[9] 514 1070 41.5 3694 8.67 0.52 - 40 69P2O5-15Na2O-15CaO[9] 514 1069 38.9 2337 4.78 0.52 - 52 J. Pure App. Chem. Res.,

2016, 5 (3), 148-156 26 September 2016 26 September 2016 X The journal homepage www.jpacr.ub.ac.id p-ISSN : 2302 – 4690 | e-ISSN : 2541 – 0733 154 Phosphate Glass Compositions 4F3/2 ? 4I11/2 transition ? ex (nm) ? p (nm) ? ? eff (nm) AR (s-1) e(p) x10- 20 (cm2) R R (s) ? exp (? s) 69P2O5-22,5Na2O-7,5Li2O[9] 514 1071 37.59 1810 3.99 0.52 - 82 69P2O5-15Na2O-7,5Li2O-7,5K2O [9] 514 1070 36.76 2809 3.95 0.52 - 51 69P2O5-22,5Na2O-7,5K2O[9] 514 1069 36.23 1874 3.90 0.52 - 74 93NaH2PO4H2O-5LiF [10] 807 1055 26.3 - 6.7 0.55 350 160 93NaH2PO4H2O-5BaF2 [10] 807 1055 26.4

- 3.5 0.54 377 170 88NaH2PO4H2O-5LiF -5BaF2[10] 807 1055 26.5 - 3.52 0.55 358 170 55P2O5-17K2O-12MgO-6MgF2- 9Al2O3[12] 355 1056 40.4 - 1.81 0.63 491 200 55P2O5-17K2O-12SrO-6SrF2- 9Al2O3[12] 355 1054 32.6 - 3.29 0.64 326 211 0.1Al(PO3)3-0.1Ba(PO3)2-0.4(Mg- Ba)F2[15] 800 1058 32 3238 2.68 0.44 358 185 58.5P2O5-17K2O-14.5SrO- 9Al2O3[19] 355 1051 27.95 - 4.05 0.52 319 172 55.5P2O5-17K2O-14.5SrO-8Al2O3- 4AlF3[19] 355 1051 23.72 - 5.08 0.50 290 188 55.5P2O5-17K2O-11.5SrO-9Al2O3- 6BaF2[19] 355 1051 23.51 - 4.72 0.5 306 194

20Al(PO3)3-60MgF2-20NaF- 1NdF3[21] 800 1054 28.5 1801 4.51 0.365 - 271 Na2O-Al2O3-B2O3[22] 880 1057 - 1500 3.1 0.44 295 59 K2O-BaO-Al2O3-P2O5[22] 880 1057 - 1200 2.3 0.45 376 43 ZnO-Li2O-P2O5[22] 880 1057 - 1600 3.2 0.45 284 54 Stimulated emission cross section for the 4F3/2 4I11/2 transition can be calculated by equation [15]: (5) Where c is the speed of light in vacuums and n is the refractive index. The variation of emission cross section for several phosphate glasses which contained with Nd3+ were listed in Table 3.

The smallest value at 1.81 x10-20 cm2 of the emission cross section produced by 55P2O5-17K2O-11MgO-6MgF2-9Al2O3 glass composition[12], whereas the highest value obtained at 8.67 x10-20 cm2 by 69P2O5-15Na2O-15K2O glass composition [9] with the Nd3+ ion concentrations doped are 1.0 mole% respectively.

The distribution of the emission cross section for Nd3+ doped phosphate glasses are shown in Fig. 6. Generally, the laser medium candidate based on Nd3+ doped phosphate glasses showed that the average magnitude distribution of the emission cross section are approximately 4.0 x10-20 cm2 to 5.0 x10-20 cm2.

In the case of phosphate glasses as a laser medium candidate, the radiative parameters and performance of the laser can be improved by using fluorophosphate glass as host matrix [2,5,7,10,19]. The calculated branching ratio in Table 3 for 4F3/2 ? 4I11/2 transition can be fitted with the quality factor ? , explain about efficiency of lasing transition.

The magnitudes range of branching ratio in this discussion showed minimum at 36.5% and maximum at 65% which generally achieved approximately at 50%. The radiative transition probability and radiative lifetime of 4F3/2 ? 4I11/2 manifold for Nd3+ lasing have been shown and compared among phosphate glasses in Table 3. The longest radiative lifetime for this study transition is shown by 55P2O5-17K2O-12MgO-6MgF2-9Al2O3-1Nd2O3 composition with quantum efficiency at J. Pure App.

Chem. Res., 2016, 5 (3), 148-156 26 September 2016 26 September 2016 X The journal homepage www.jpacr.ub.ac.id p-ISSN : 2302 – 4690 | e-ISSN : 2541 – 0733 155 40.73%. The radiative lifetime is influence the radiative decay rate caused by differences of the crystal-field environment at the Nd3+ site and non-radiative decay rate caused by multiphonon relaxation [12].

CONCLUSION The Nd3+ ions doped phosphate and fluorophosphate glasses have been discussed that started from host matrix composition, ions concentration, oscillator strength, Judd-Ofelt parameters and radiative transitions. The content of neodymium ions in phosphate glasses to be applied as a laser medium is 1.0 mole%. The quenching effect of 1.0 mole% Nd3+ ion luminescence obtained is smaller due to the lower concentration of OH-.

The utilization of fluorophosphate, alkali oxide and alkaline oxide are also recommended as a mixture of glass material to improve the radiative properties of the laser. In this investigation has found some increase in the laser performance such as the high stimulated emission cross section, long radiative lifetime fluorescence and wider the bandwidth generated by Nd3+ doped fluorophosphate glasses.

The magnitudes were produced by this glass has also been adapted to commercial laser medium and almost the same even to be better than the commercial lasers. Judd-Ofelt analysis declared that most of the relationship between ? ? parameters indicates on ? 2 > ? 6 > ? 4 for Nd3+: phosphate glasses but the trends do not always occur to general trends especially for phosphate glasses.

The radiative properties of the 4F3/2 ? 4I11/2 transition for Nd3+: phosphate glasses potential lasing which found to be higher at 69P2O5- 15Na2O-15K2O-1Nd2O3 composition. In this glass has enhanced the radiative transition probability as well as branching ratio and stimulated emission cross section are 3694 s-1, 52% and 8.67 x10-20 cm2 respectively. ACKNOWLEDGMENT The author would like to thank DIKTI, Ministry of Education and Culture, Rep.

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